Estimation of the 1995 Seymour River Sockeye Salmon *(Oncorhynchus nerka)* Escapement

R. Houtman and N.D. Schubert

Fisheries and Oceans Canada
Science Branch, Pacific Region
100 Annacis Parkway, Unit 3
Delta, British Columbia
V3M 6A2

2000

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2536

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101-02639/

Canadian Manuscript Report of

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Fisheries and Oceans Canada

Science Branch, Pacific Region

100 Annacis Parkway, Unit 3

Delta, British Columbia

V3M 5P8

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Cat. No. Fs 97-4/2536E ISSN 0706-6473

Correct citation for this publication:

Houtman, R. and N.D. Schubert. 2000. Estimation of the 1995 Seymour River sockeye salmon (*Oncorhynchus nerka*) escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2536: 41 p.

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ABSTRACT

Houtman, R. and N.D. Schubert. 2000. Estimation of the 1995 Seymour River sockeye salmon (*Oncorhynchus nerka*) escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2536: 41 p.

In 1995, the Department of Fisheries and Oceans conducted a mark-recapture study to estimate the escapement of early summer sockeye salmon (*Oncorhynchus nerka*) to the Seymour River. Sockeye were captured at two sites in the lower Seymour River and one site in the upper Seymour River; 884 were released with disk tags and secondary marks. The spawning grounds were surveyed through the period of spawning and die-off; 7,516 carcasses were recovered, of which 162 were marked. Analysis revealed a temporal recovery bias and a spatial recovery bias in males; however, because the 95% confidence intervals of the pooled Petersen estimates overlapped those of the spatially and temporally stratified estimators, it was concluded that the pooled Petersen population estimates were not seriously biased. The 1995 escapement to the Seymour River was estimated, using the pooled Petersen estimator, at 20,224 adult males, 20,463 adult females and 0 jacks. Study design changes, including increased and improved allocation of sampling effort, improved resurvey procedures and the assessment of disk tag loss and handling stress, are recommended.

RÉSUMÉ

Houtman, R. and N.D. Schubert. 2000. Estimation of the 1995 Seymour River sockeye salmon (*Oncorhynchus nerka*) escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2536: 41 p.

En 1995, le ministère des Pêches et des Océans a mené une étude de marquage-recapture pour estimer l'échappée de la remonte hâtive d'été de saumon rouge (*Oncorhynchus nerka*) dans la rivière Seymour. Les saumons ont été capturés à deux stations du cours inférieur de la rivière, et à une station du cours supérieur; 884 spécimens ont été libérés après avoir été marqués avec des disques et des marques secondaires. Les frayères ont été surveillées pendant toute la période de fraye et de mortalité; 7 516 carcasses ont été récupérées, dont 162 étaient marquées. L'analyse a révélé un biais temporel dans la récupération, et un biais spatial dans la récupération des mâles; toutefois, étant donné que les intervalles de confiance de 95 % des résultats obtenus avec l'estimateur multiple de Petersen chevauchaient ceux des estimateurs stratifiés spatialement et temporellement, il a été conclu que les estimations Petersen de la population n'étaient pas gravement biaisées. L'échappée de 1995 dans la rivière Seymour a été estimée, à l'aide de l'estimateur multiple de Petersen, à 20 224 mâles adultes, 20 463 femelles adultes et 0 mâle précoce. Il est recommandé d'apporter des modifications au plan d'étude, notamment un accroissement et une meilleure répartition de l'effort d'échantillonnage, d'améliorer les procédures de deuxième relevé et d'évaluer les pertes de disques et le stress dû à la manipulation.

INTRODUCTION

The Fraser River system supports the largest population of sockeye salmon (*Oncorhynchus nerka*) in the world (Northcote and Larkin 1989). Sockeye spawn in over 150 natal areas, ranging from small streams to large rivers and lakes, which are distributed throughout the accessible portion of the Fraser River system. The Department of Fisheries and Oceans estimates the stock-specific annual abundance of Fraser River sockeye spawners using a two-tiered system originally developed by the International Pacific Salmon Fisheries Commission. Stocks with forecasted escapements above 25,000 are assessed using enumeration fences or mark-recapture studies, while stocks with smaller escapements are assessed using visual techniques.

The Seymour River is located in the South Thompson River system at the north end of Shuswap Lake's Seymour Arm (Fig. 1). The system supports sockeye salmon populations that spawn in the Seymour River and its principal tributary, McNomee Creek (Fig. 2). There are two temporally distinct stocks, a small late run and a larger early summer run. The late run arrives on the spawning grounds in October and spawns almost exclusively in the Seymour River. The early summer run arrives on the spawning grounds in August and spawns in both the Seymour River and McNomee Creek (Fig. 2). Schubert (2000) describes the estimation of the 1995 escapement of late run sockeye and early summer run sockeye spawning in McNomee Creek. This report describes the estimation of the early summer run sockeye salmon that spawned in the Seymour River in 1995.

Escapements of early run sockeye to the Seymour River system have been assessed at least since 1902 following the construction of the Granite Creek Hatchery, and have been reported regularly since 1939. The stock exhibits a quadrennial escapement cycle, with abundance increasing on three of the cycles since the early 1980's. Escapements in the 1950's and 1960's versus the 1980's and 1990's increased from 41,000 to over 130,000 on the 1990-1994 dominant cycle, from 34,000 to 73,000 on the 1991-1995 subdominant cycle, and from 4,000 to 12,000 on the 1988-1992 off-cycle. Escapements on the 1989-1993 cycle have remained at about 8,000 fish (Appendix 1).

Dominant and subdominant escapements have exceeded 25,000 almost every cycle year since 1958; consequently, mark-recapture studies have been used to estimate the escapement on these cycles since 1963 (Appendix 1). Schubert (1997) described the mark-recapture study conducted in the Seymour River system in 1994. The 1995 study was similar, but included modifications designed to reduce sample selectivity and to facilitate assessment of tag loss and the effects of sub-acute and acute stress. Specific modifications include:

- An additional tagging site in the upper Seymour River,
- Standard and low-stress tagging procedures,
- Secondary marks (opercular punches) on all tagged fish,
- Similar recovery survey frequencies in all recovery areas,
- More frequent resurveys and feedback about missed tags to recovery personnel.

This report describes the study design, field methods and analysis of the study to estimate the escapement of early summer run sockeye salmon to the Seymour River, in 1995. Included are estimates of the adult age and length distributions, and escapement by sex and age. As well, mark-recapture biases are evaluated, including a comparison of escapement estimates calculated using alternative models. The report concludes with a discussion of the results and recommendations for the design of future studies.

STUDY AREA

The Seymour River originates in the Monashee Mountains of south central British Columbia and flows south for 66 km, entering Shuswap Lake at the north end of Seymour Arm (Fig. 1). The river and its two main tributaries, McNomee and Ratchford creeks, drain a steep, glaciated watershed of approximately 805 km^2. Near the mouth, the Seymour River has a mean daily discharge of 36 m^3s^{-1} (1915-1990), with mean daily maxima (114 m^3s^{-1}) and minima (6 m^3s^{-1}) occurring in June and January, respectively (Environment Canada 1991).

The Seymour River was divided into five areas (Fig. 2) based on homogeneity of physical characteristics and to provide the data aggregations required for bias testing. Areas 1-3 comprise the upper section of the part of the river accessible to sockeye salmon. In this section, the

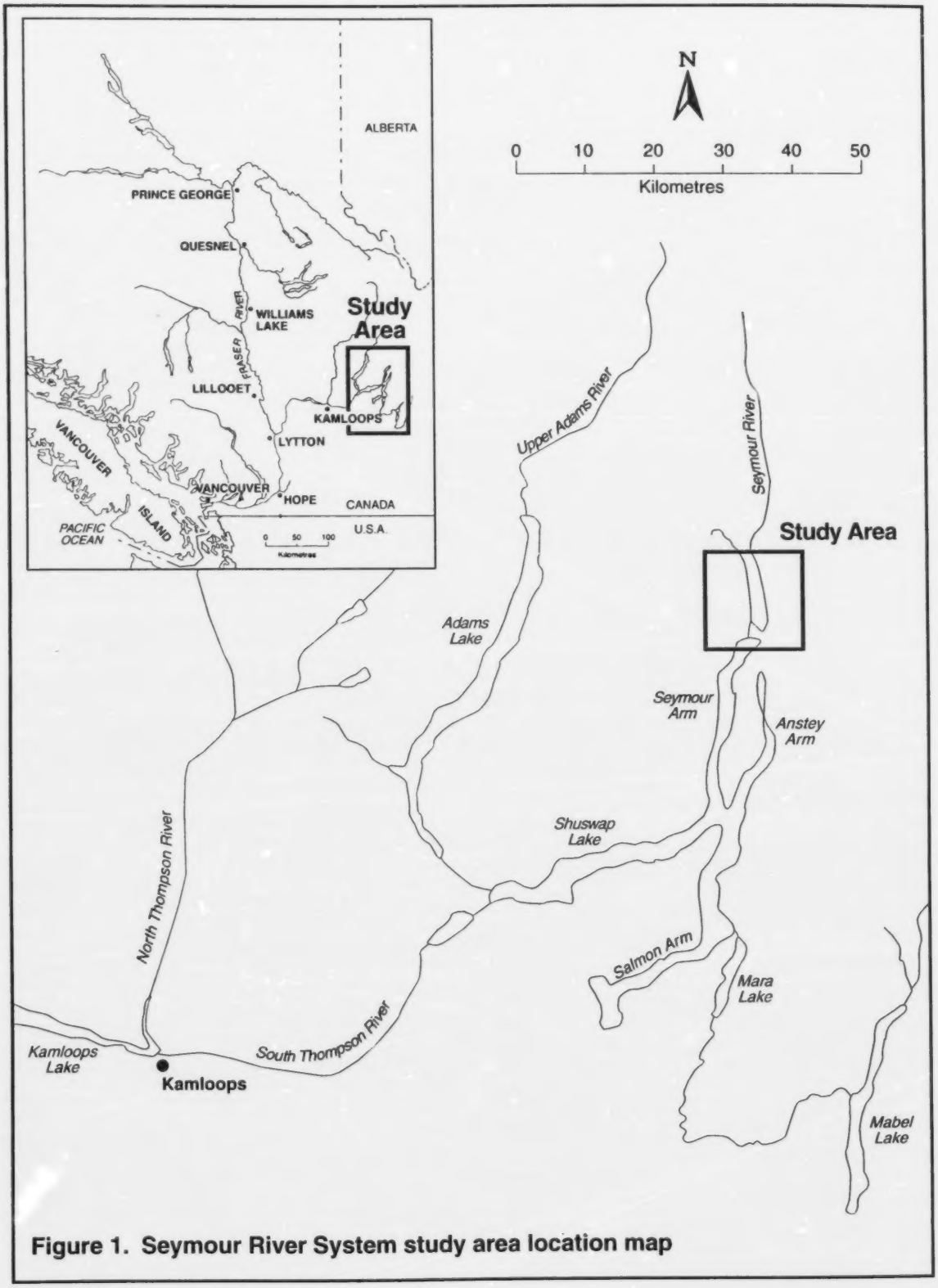
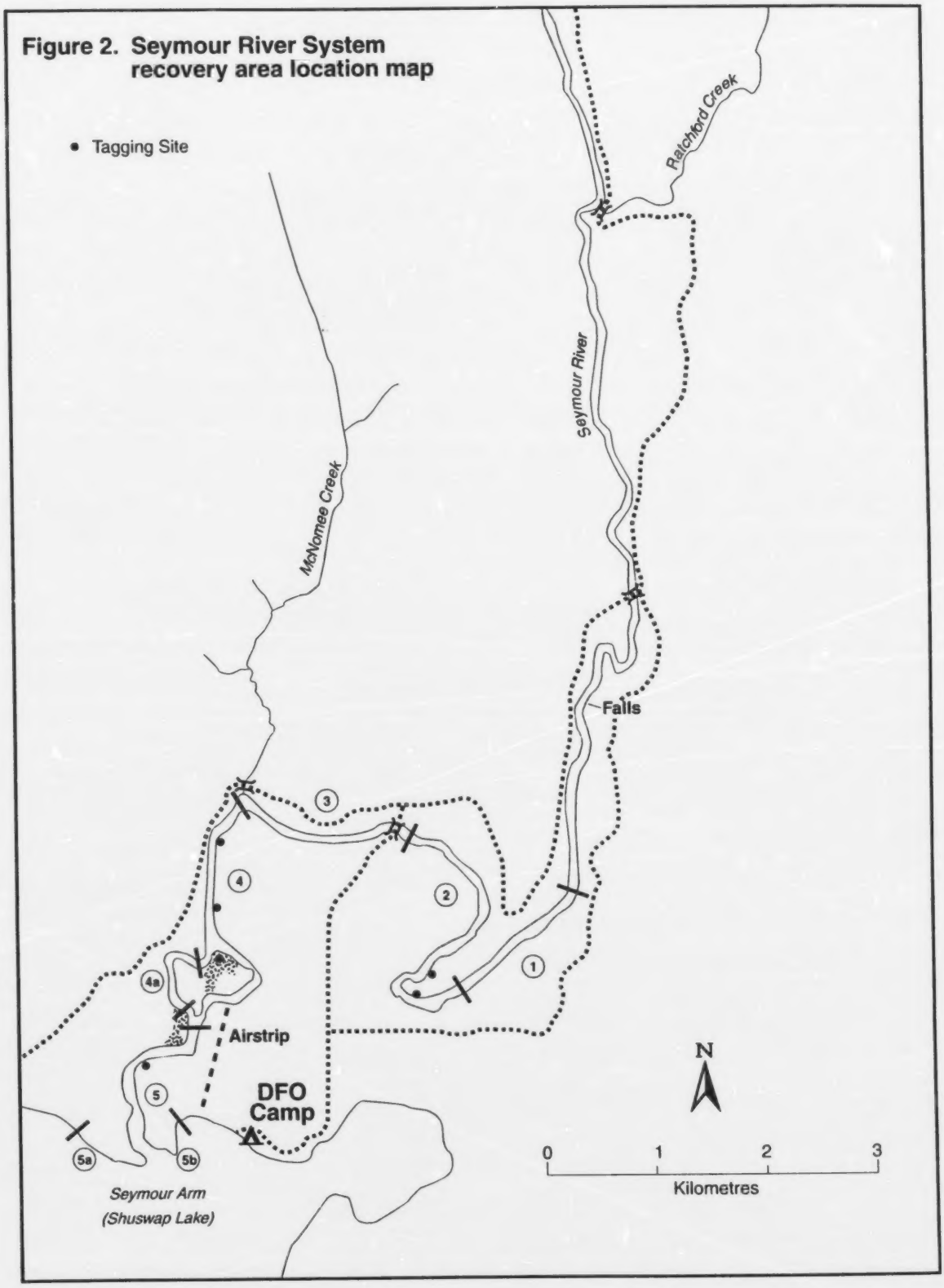


Figure 1. Seymour River System study area location map

Figure 2. Seymour River System recovery area location map



river is confined to a single channel which has a maximum width of 40 m and a gradient of 0.6% (Sebastian MS 1983). The substrate is predominantly large gravel and cobble, and the spawning density is light except in discrete areas.

Area 1 (3.5 km) extends downstream from an impassable falls located 12.3 km upstream to a point immediately above the horseshoe-like bend in the river. The gradient is relatively high, the water depth is 1 m and the substrate is predominantly cobble and boulders.

Area 2 (2.9 km) extends downstream to a short bedrock canyon which is spanned by a road bridge. The channel gradient declines in the upper part of Area 2, resulting in a short section with predominantly gravel substrate. The horseshoe consists of a 0.9-km long section where the gradient is low and the depth increases to 5 m. The remainder of the area is similar to Area 1, except the channel has a lower gradient and scattered gravel.

Area 3 (1.6 km) extends from the bridge to McNomee Creek. The channel gradient is higher than in Area 2, resulting in a predominantly cobble substrate.

In areas 4-5, the gradient is lower (0.3%) and the river changes from a single channel to one which is wide and unconfined. The substrate is predominantly gravel, and spawning density is high. Area 4 (2.8 km) extends from McNomee Creek downstream to a point near the end of the airfield. The river flows in a single 25 m wide channel for 1.3 km, then forms two main branches (the west branch is Area 4a) and a number of side channels which reform into a single channel 1.5 km above the mouth. Debris jams contribute to frequent channel shifts by scouring pools and creating new side channels.

Area 5 (1.5 km) extends downstream to Shuswap Lake and includes 0.5 km of lakeshore west (Area 5a) and east (Area 5b) from the river mouth. The river is characterized by a wide flood plain with extensive side channels.

FIELD METHODS

VISUAL SURVEYS

Visual counts of live sockeye spawners in the Seymour River were made, by an observer standing in an inflatable boat, every three to four days until the peak of abundance was observed.

TAG APPLICATION

Capture and tagging procedures were designed to tag at least 1% of the escapement, and to distribute those tags among adult males, females and jacks in a spatially and temporally representative manner. Sockeye were captured by beach seine at sites located in areas 2, 4 and 5 (Fig. 2); the Area 2 site was added, as recommended by Schubert (1997), to improve the distribution of tags in the population, especially among upriver spawners. Because an independent estimate of daily abundance was unavailable, similar daily effort (typically one set per site per day) was applied throughout the run to achieve temporally proportional tag application. Tagging began one day after sockeye were first observed and continued until low abundance indicated the immigration was virtually complete.

Sockeye were captured by a four-person crew using a 36.5 m x 3.8 m x 5 cm-mesh beach seine net. The net was set from an inflatable boat in a downstream arc and withdrawn from the river to enclose an area of water along the riverbank. Captured fish were held in the net until removal for tagging. Previously tagged fish were identified upon recapture and immediately processed to avoid additional stress. The tag number was recorded and the tag checked; if damaged by recapture, it was replaced with a new tag. Other species and sockeye that were injured or showed advanced stages of maturation were released untagged.

Fish were tagged in a flexible plastic trough (12 cm x 20 cm x 100 cm) suspended in a wooden tray with a metre stick attached. In order to evaluate the susceptibility of this population to tagging-induced stress, standard and low stress tagging procedures were alternated every fish. Standard procedures entailed tagging the fish with the tray elevated from the water surface and releasing it by throwing it the minimum necessary distance over the net's cork line. Low stress procedures entailed tagging the fish with the tray immersed in 15 cm of water and releasing it by lowering a section of the cork line; at no time was the fish removed from the water. Handling time for both procedures averaged 25-30 seconds. In addition, the following general fish handling guidelines were adopted in 1995 to reduce tagging-induced stress: activity within the net was minimized to reduce siltation; fish were removed from the water only when a tagger was ready and processed as quickly as possible; and, when removed from the water, the fish were

cradled in two hands rather than dangled by the caudal peduncle.

The disk tags consisted of two red 15 mm diameter laminated cellulose acetate disks threaded through centrally punched holes onto a 77 mm long nickel pin. The pin was inserted with pliers through the musculature and pterygiophore bones approximately 12 mm below the anterior portion of the dorsal fin insertion. The disk tags, arranged with one on each side of the fish, were secured by twisting the pin into a double knot. One disk per pair was numbered with a unique code. Each tagged fish received a secondary mark to permit an assessment of tag loss. These consisted of one (males) or two (females) 7 mm diameter holes punched through the right operculum using a single hole punch. Care was taken to avoid gill tissue damage. Date and location of capture, disk tag number, nose-fork (NF) length (±0.5 cm), sex (fish with a NF length less than 50 cm were recorded as jacks), number of opercular holes punched, tagging method, and marks (hook, gill net and lamprey) were recorded for each fish released with a disk tag. Condition at release was recorded as 1 (swam away vigorously), 2 (swam away sluggishly) or 3 (required ventilation).

SPAWNING GROUND SURVEYS

Recovery Survey

The carcass recovery surveys were designed to achieve equal recovery probabilities among strata. Thus, surveys began after the first carcasses were observed near the tagging site and continued until the die-off was virtually complete, the entire shoreline of all areas were examined in each survey, surveys were performed at similar rates (requiring two to three days to survey the entire system) and each survey began immediately upon completion of the previous one. Surveys were conducted on foot by two-person crews using an inflatable boat to leapfrog down the river; up to two crews were required at the peak of die-off.

The crews were trained to recover carcasses independent of their tag status and, following recovery, to place a higher priority on the correct identification of tag and secondary mark status than on survey speed. All carcasses that were on shore or retrievable with a peough by wading into the river to knee depth were enumerated (except predator kills, which were excluded from the survey), and either chopped in two with a machete or thrown on the bank above the high water mark. Carcass recoveries were recorded by date, area, sex, tag and secondary mark status, carcass condition (fresh, tainted or rotten) and female spawning success (0%, 50% or 100% spawned). If a disk tag was present, it was retrieved and the tag number was recorded before the carcass was processed.

Carcasses in deep pools (hereafter, 'pool recoveries') were sampled opportunistically using a beach seine net set from an inflatable boat and sampled as described above. These data were used to test if the mark incidence (the proportion of carcasses with disk tags and/or secondary marks) was similar to that among standard (shore) recoveries.

Resurvey

Previously processed carcasses were reexamined through the recovery period to identify disk tagged carcasses that had been erroneously classified as untagged. The resurvey, conducted by experienced technicians only, recorded carcasses by date, area, sex and mark status. Schubert (1997) identified deficiencies in the 1994 resurvey that were addressed by more frequent and extensive survey effort.

On the initial survey, tags were removed from carcasses identified as disk tagged, but those carcasses were not excluded from the resurvey. The number of fish with only secondary marks which were misclassified as unmarked, therefore, could not be determined.

BIOLOGICAL SAMPLING

Biological samples were obtained following a protocol provided by the Pacific Salmon Commission. One hundred and eighty sockeye carcasses of each sex were sampled for postorbital-hypural plate (POH) and nose-hypural plate (standard) lengths (±0.5 cm), otoliths and scales (one from each preferred region, as defined by Clutter and Whitesel (1956)). Sampled carcasses were selected randomly from recoveries on the Seymour River only, over several days near peak die-off (based on the historic mean date). All recovered jacks were sampled for scales and lengths.

Near the peak of arrival, 25 randomly selected females were killed at the tagging sites (10 and 15 in areas 4 and 5, respectively). Each was sampled as above, and the egg skeins and

loose eggs were removed, placed in a cotton bag and preserved in a 10% formaldehyde solution. The number of eggs in each sample was estimated as the product of the total skein weight (grams) and the number of eggs per gram in a weighed subsample of the skein, plus a count of the loose eggs.

ANALYTIC PROCEDURES

Analytic procedures are presented in three sections. The first section describes the procedures by which the data were evaluated and corrected for sex and tag identification error, tag loss, and acute stress effects. The second explains the procedure used to evaluate potential sampling biases. The results of this analysis were used to guide evaluations of bias in the resulting population estimates and the need to adopt stratified estimators. Finally, the third section describes the procedures used to calculate population estimates, and to evaluate alternative estimates.

DATA ADJUSTMENTS

Sex Identification Error

The application data were corrected for sex identification error by comparing the sexes recorded at release and carcass recovery. All errors are assumed to be made at application, because the development of sexually dimorphic traits was less advanced at application, recording errors were more likely to occur during the hectic tagging process and carcasses of ambiguous sex could be incised and examined internally.

The corrected total number of adult males (defined as males with NF $\geq$ 50 cm; hereafter, 'males') tagged (M_m*) was estimated using an equation provided by Staley (1990). The corrected number of male sockeye tagged in a given application 'stratum' was estimated by multiplying the fraction of all fish released as males that were released in that stratum by M_m*. The corrected number of adult females (hereafter, females) tagged in that stratum was estimated as the total number of adults actually released minus M_m*.

Tag Recognition Error

Resurvey data were used to correct the carcass recovery totals for tags missed by the initial survey. The number of missed tags was estimated, by sex, as the product of the tag incidence in the resurvey and the number of carcasses examined on the initial survey. For stratified population estimates, these recoveries were added to recovery strata in proportion to the fraction of total disk tagged carcasses recovered in each stratum.

Tag Loss

Because all fish released with a tag also received a permanent secondary mark, the rate of tag loss between application and carcass recovery equals the ratio of recoveries with only secondary marks to those with disk tags and/or secondary marks. The number of recoveries with disk tags and/or secondary marks was used to calculate the population estimate. For stratified population estimates, these recoveries were added to application strata in proportion to the fraction of the total application sample applied in each stratum.

Emigration

Initially, the mark-recapture study area included McNomee Creek. Due to sampling biases in McNomee Creek (low tag incidence, described below, and probable high recovery rates), however, the analysis was modified to limit the population estimated by mark-recapture to the Seymour River. First, for all subsequent analyses, tagged and untagged McNomee Creek carcass recoveries were excluded from the application and recovery samples. Second, before calculating mark recapture estimates, the estimated number of unrecovered tagged carcasses in McNomee Creek was removed from the application sample. This number was estimated, separately for males and females, as the product of the tag incidence and the visual survey-based population estimate for McNomee Creek. For stratified population models, the removal was proportional to the number of tags applied in each application stratum.

Handling Stress

Tagging-induced stress can influence post-tagging behavior and the timing and probability of recovery. The data, therefore, were evaluated to determine whether specific tags should be excluded. First, chi-square tests were used to test whether the proportion of tagged fish recovered was influenced by three potential stress factors: tagging method, release condition and the number of times tagged fish were recaptured in subsequent beach seine sets. When a test result

was significant, the high stress group was excluded from subsequent analyses. (In this report, significant ($P<0.05$) and highly significant ($P<0.005$) test results are indicated with a single and double asterisk, respectively.) Second, fish recovered less than five days after release were excluded. While five days is an arbitrary criterion, unusually short times between application and recovery are typically associated with poor spawning success and are assumed to result from tagging stress.

Pool Recoveries

Pool recoveries were excluded from the recovery sample because they were not sampled representatively. This procedure will not cause bias in the population estimates if none of those carcasses removed from deep pools would have subsequently become available to standard recovery.

TESTS OF SAMPLING ASSUMPTIONS

Statistical tests were performed to assess whether application and recovery were proportional and whether complete mixing occurred (Seber 1982; p 434-9; Schwarz and Taylor 1998). The data were examined for temporal, spatial and fish sex biases at application and recovery. Application bias (non-proportional application and incomplete mixing) was assessed by stratifying the recovery sample (not corrected for missed tags) and comparing the mark incidence (the proportion of carcasses with disk tags and/or secondary marks) among strata. Similarly, recovery bias (non-proportional recovery and incomplete mixing) was assessed by stratifying the application sample and comparing the proportion recovered among strata. The data used for the recovery bias tests are adjusted for sex identification error and handling stress, but not for tag loss (the application stratum of fish with only a secondary mark could not be determined). Comparisons were made using chi-square tests (Sokal and Rohlf 1981).

For temporal bias tests, the application and recovery samples were stratified into four periods of approximately equal duration, total effort (numbers of sets or recovery surveys) and sample size. These three stratifications were used to examine the sensitivity of the tests to period start and end dates. For spatial bias tests, the application sample was stratified by application site and the recovery sample was stratified into three sections: upper Seymour River (areas 1, 2 and 3), lower Seymour River (areas 4, 4a and 5), lakeshore (areas 5a and 5b).

The data were also examined for a size bias at recovery; application bias could not be assessed because unmarked carcasses were not measured. The cumulative NF length frequency distributions of recovered and unrecovered portions of the application sample were compared using a Kolmogorov-Smirnov two-sample test (Sokal and Rohlf 1981). For the male test, males smaller than 50 cm NF were included. A significant difference would indicate that the recovery sample was not random with respect to fish size.

A chi-square test was used to examine whether mark status influenced spawning success. The proportion of incompletely spawned (0 or 50% spawning success) females was compared between marked and unmarked recoveries. Although a difference in this trait could result from sampling selectivity, tagging stress would most likely cause such a difference. For example, a study in coho salmon (*O. kisutch*) showed that spawning success was affected by electroshocking, a highly stressful capture technique (Schubert *et al.* 1994). Thus, this test is interpreted as indicating whether fish were stressed by tagging.

Finally, to test the assumption of equal recovery probabilities of marked and unmarked fish (discussed below), the mark incidence among pool recoveries was compared with that among standard recoveries using a chi-square test.

ESTIMATION OF SPAWNER POPULATION

Seymour River escapement was estimated using the simple or pooled Petersen estimator ("PPE"; Seber 1982) and two stratified estimators, the maximum likelihood Darroch estimator ("MLE"; Plante 1990; Arnason *et al.* 1996) and the Schaefer estimator (Seber 1982). The estimates were calculated using Stratified Population Analysis System software (Arnason *et al.* 1996), from mark-recapture data adjusted for sex and tag recognition errors, emigration to McNomee Creek and handling stress effects.

Stratified population estimates were calculated using both temporal and spatial data arrays. The initial application and recovery strata were the same as those used in the bias tests (described above), for both temporal (periods of similar sample size) and spatial data arrays. Selected strata were then pooled when neces-

sary to generate an estimate and satisfy assumptions of the MLE as assessed by Plante's goodness-of-fit test (Arnason *et al.* 1996). This selective pooling also permitted an evaluation of model sensitivity and stability. For temporally stratified data, only temporally 'adjacent' strata were pooled, and the stratum with the smallest number of tags applied or recovered was generally pooled. For spatially stratified data, lakeshore and lower river recovery sections were pooled if necessary. Population estimates were calculated after each pooling step.

Sampling biases were addressed in two ways. First, population estimates were calculated for each sex because sex biases are common in mark-recapture studies. Second, spatial and temporal biases were evaluated by comparing the PPE and MLE estimates. The latter are considered most accurate, and therefore accepted, when the 95% confidence intervals of the two estimates did not overlap; otherwise, the PPE estimates are accepted, because their precision is generally higher. Schaefer estimates were only calculated for comparison; they were not considered for use as the final population estimates because no precision estimates are available.

RESULTS

VISUAL SURVEYS

The Seymour River was surveyed four times between August 21 and September 1, 1995 (Appendix 2). The peak live count, 28,478, was recorded on August 28. At the peak, 62% of the spawners were in the lower Seymour River (areas 4, 4a, and 5); the most populous areas were 4 (35%) and 2 (25%).

TAG APPLICATION

Beach seining began on August 19, and sockeye were tagged between August 20 and September 8, 1995 (Appendix 3). A total of 939 sockeye adults and one jack were tagged, with 11.6% applied in Area 2, 62.0% in Area 4 and 26.4% in Area 5. The sex of one (0.94%) recovered male and none of the recovered females was recorded incorrectly at the time of tagging. When corrected for this error, an estimated 555 (59.1%) males and 384 (40.9%) females were marked.

Two sets of fish were removed from the application sample before testing sampling assumptions. First, 7 males and 10 females recovered in McNomee Creek (one female recovered as a male) were removed. Second, one male released on August 30 and recovered on September 2, and one female released on September 5 and recovered on September 8, were removed from the application sample because they were recovered less than five days after tag application. The proportion of tagged fish recovered in potential high-stress and corresponding low-stress groups did not differ significantly for any of the three potential stress factors examined: tagging method, release condition and the number of recaptures (Table 1); therefore, fish in the high-stress groups were retained.

An estimated 4,239 males and 3,820 females spawned in McNomee Creek (Schubert 2000); the tag incidence among carcasses recovered from this population was 0.60% for males and 0.75% for females (see below). Based on these values, the estimated number of unrecovered, tagged carcasses in McNomee Creek was 17.6 males and 19.8 females. These numbers were removed from the application sample before calculating the population estimates, and the final application sample included 530 males, 353 females and one jack (Table 2).

The mean (S.D.) NF length for males, females and jacks in the application sample was 63.1 (2.7) cm, 59.6 (2.6) cm and 43.5 cm, respectively; ageing samples (*i.e.*, otoliths or scales) were not obtained for any tagged fish. The incidence of net, lamprey and hook marks was 6.2%, 5.6% and 1.1% in males, 9.8%, 2.6% and 1.0% in females, and 0%, 0% and 0% in jacks, respectively (Appendix 4).

SPAWNING GROUND SURVEYS

Recovery survey

A total of 3,818 male, 3,698 female and 0 jack sockeye carcasses were recovered using standard methods in the Seymour River between August 22 and September 18, 1995 (Table 2; Appendix 5). Areas of the Seymour River were surveyed an average of 11 times, resulting in 7,516 recoveries, 75% of the total. Most carcasses were recovered in areas 4 (35.5%), 5 (31.7%) and 2 (14.3%).

Of the total recovery, 97 (2.5%) males and 63 (1.7%) females were disk tagged; no secondary marked carcasses were found without disk tags (Table 2; Appendix 5). Time between release and recovery averaged 12.8 days for males and 13.4

Table 1. The influence of three potential stress factors on the proportion of tags recovered; test data and results for Seymour River sockeye salmon, 1995.

	Disk tags applied[a]			Disk tags recovered			Percent recovered		
Test of:	Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Tagging method									
Standard	304.9[b]	157.1[b]	0	51 [b]	26 [b]	0	16.7%	16.5%	-
Low stress	243.3	216.7	1	47	38	0	19.3%	17.5%	0.0%
Release condition [c]									
1	540.1[b]	365.9[b]	1	96 [b]	62 [b]	0	17.8%	16.9%	0.0%
2	3.0	2.0	0	1	1	0	33.0%	50.8%	-
3	1.0	0.0	0	0	0	0	0.0%	-	-
Number of recaptures									
0	507.8[b]	347.2[b]	1	88 [b]	62 [b]	0	17.3%	17.9%	0.0%
1-5	40.4	26.6	0	10	2	0	24.8%	7.5%	-

Chi-square test results	Male			Female		
Stress factor	χ^2[d]	df	*P*	χ^2[d]	df	*P*
Tag application method	0.45	1	0.50	0.01	1	0.91
Release condition						
1 vs 2+3:	0.08	1	0.77 [e]	0.10	1	0.76 [e]
Number of recaptures						
0 vs 1-5 recaps:	0.97	1	0.33	1.21	1	0.27

[a] Corrected for sex identification errors.

[b] Includes one fish recovered less than five days after tagging.

[c] Release condition was not recorded for 10 fish at application, 2 of which were recovered.

[d] χ^2 values are Yates corrected.

[e] Test result inaccurate due to small sample size in some cells.

days for females, and was significantly longer among those tagged earlier in the study (Table 3; $p<0.05$, t-test). Average time between tagging and recovery was not affected by either tagging site or recovery section ($p>0.05$, ANOVA). The two fish that were recovered less than five days after tagging were recovered in areas 4 (female) and 5 (male; Appendix 5). Female spawning success averaged 98.3%, with lower success among the early spawners (Table 3); a comparison of the proportion of incomplete spawners (0 or 50% spawning success) in the early and late recoveries indicated that this difference was significant ($p<0.05$, chi-square). Spawning success also varied significantly ($p<0.05$, chi-square) by recovery section, and was lowest in the lower Seymour River (98.0%) and highest in McNomee Creek (99.7%).

Pool recoveries were made on September 10 and 12 in a deep pool in Area 2; 56 males and 170 females were recovered, of which 1 (1.8%) male and 2 (1.2%) female carcasses had disk tags (Appendix 5b).

Resurvey

Each area was resurveyed, twice on average, between September 3 and September 15, 1995; 1,744 males and 1,207 females were re-examined, and 1 disk tag (male) was recovered (Appendix 6). An estimated 2.2 (2.2%) and 0 disk tagged male and female carcasses, respectively, processed during the main survey were not correctly identified as tagged fish (Table 2). When corrected for this error, a total of 99.2 male and 63 female disk tags were recovered, a mark incidence of 2.6% and 1.7%, respectively.

Table 2. Sockeye tagged, total carcasses recovered and marked carcasses recovered, by sex, for Seymour River sockeye salmon, 1995.

Sex	Disk tags applied [a, b, c]	Total recovery [b, d]	Marked sockeye carcasses recovered: Both marks present [b, d]	2° mark only	Resurvey adjustment	Total	Percent recovered	Mark incidence
Male	530	3,818	97	0	2	99	18.7%	2.6%
Female	353	3,698	63	0	0	63	17.8%	1.7%
Jack	1	0	0	0	0	0	0.0%	-
Total	884	7,516	160	0	2	162	18.4%	2.2%

[a] Corrected for sex identification error.

[b] Excludes one male and one female recovered less than five days after tagging.

[c] Excludes 17.6 males and 19.8 females estimated to have emigrated to McNomee Cr.

[d] Excludes 8 male and 9 female tagged sockeye recovered in McNomee Cr (1 male was tagged as a female).

Table 3. Average elapsed time between tag application and recovery and female spawning success (all recoveries), by recovery section, period and sex, for Seymour River system sockeye, 1995.

Section	Period [a]	Mean time (days) between tag application and carcass recovery: Male	(n)	Female	(n)	Female spawning success: %	(n)
Seymour River							
Lakeshore	Early	14.5	(2)	-	(0)	98.4%	(62)
	Late	12.0	(2)	-	(0)	100.0%	(39)
	Total	13.3	(4)	-	(0)	99.0%	(101)
Lower River [b]	Early	13.6	(47)	14.5	(30)	95.8%	(1,095)
	Late [c]	11.1	(30)	11.4	(20)	99.3%	(1,783)
	Total	12.6	(77)	13.2	(50)	98.0%	(2,878)
Upper River [b]	Early	14.4	(9)	15.4	(7)	96.1%	(103)
	Late	12.3	(7)	12.0	(6)	99.9%	(547)
	Total	13.5	(16)	13.8	(13)	99.3%	(650)
Total	Early	13.8	(58)	14.7	(37)	96.0%	(1,260)
	Late	11.3	(39)	11.5	(26)	99.5%	(2,369)
	Total	12.8	(97)	13.4	(63)	98.3%	(3,629)
McNomee Creek							
Total	Early	14.8	(4)	13.8	(6)	99.7%	(755)
	Late	12.5	(4)	12.7	(3)	99.9%	(430)
	Total	13.6	(8)	13.4	(9)	99.7%	(1,185)

[a] Time out to recovery: early= 19-Aug to 27-Aug releases. Female spawning success: early= 22-Aug to 9-Sep recoveries.

[b] Lower river: areas 4 and 5.

[c] Excludes 1 male and 1 female recovered 3 days after release.

BIOLOGICAL SAMPLING

Twenty-five females were sampled for fecundity on August 31, 1995, 10 from the Area 4 tag site and 15 from the Area 5 tag sites. Only 22 of them were aged; of these, 20 were age 4_2 and averaged 53.8 cm standard length (range 48.6 to 57.6 cm), and 2 were age 5_2 and averaged 62.4 cm standard length (Appendix 7). The average fecundities were 4,350 (range 2,543 to 7,118) for

age 4_2 fish and 4,625 for age 5_2 fish (Appendix 7).

The age composition of the adult carcass sample was 91.8% age 4_2 (92.6% of males and 91.1% of females) and 8.2% age 5_2 (Table 4; Appendix 8). Age 4_2 males and females averaged 49.4 and 47.8 cm, POH length, respectively; this difference was significant ($P<0.05$, t-test). On average, age 5_2 fish were 5.6 (males) and 6.0 (females) cm longer. No jacks were sampled in 1995.

SAMPLING ASSUMPTIONS

There was no influence of recovery period on mark incidence for any of the three stratifications tested, in either sex (Table 5). Mark incidence in adult carcasses ranged from 0.0% to 2.3%. No clear trend in mark incidence through time was shown. In contrast, there was an affect of application period on the proportion of tags recovered for all three stratifications tested, in both sexes (Table 6). The proportion of tags recovered ranged from 2.8% to 27.6% and generally decreased with application period.

Spatial bias was detected in the application sample for both sexes (Table 7), and in the recovery sample for males (Table 8). Mark incidence in recovered carcasses ranged from 0.0% to 2.8%. Additional tests indicate that the low mark incidence in McNomee Creek, 0.6% in males and 0.8% in females, differed significantly from that in other areas (Table 7; cf. Zar 1984). In males, the proportion of tags recovered ranged from 13.6% to 32.8%, for fish marked in areas 5 and 2, respectively (Table 8). In females, this proportion ranged from 13.9% to 20.8%, for fish marked in areas 5 and 4, respectively.

The male: female ratios among marked and unmarked recoveries, 59.3%: 40.7% and 51.1%: 48.9% respectively, differed significantly (Table 9). Thus, the application sample was selective toward males. The sex ratios among recovered and unrecovered tagged fish, 59.3%: 40.7% and 59.1%: 40.9%, did not differ (Table 9). The recovery sample, therefore, was not sex selective.

The size distributions of recovered and unrecovered tagged fish did not differ significantly for either sex, indicating that the recovery sample was not size selective (Table 10).

The mean spawning success of marked and unmarked female recoveries was 100% and 98.1%, respectively. The proportion of incomplete spawners did not differ significantly between marked and unmarked recoveries ($p>0.05$, chi-square).

Finally, the mark incidence among pool recoveries did not differ from that among standard recoveries (Table 11). Note, however, that this test had low power and may have been biased due to small sample size. All tests of sampling assumptions are summarized in Table 12.

SPAWNING POPULATION ESTIMATES

The 1995 Seymour River sockeye escapement estimates, based on the pooled (Table 2) and stratified (Table 13 and 14) data, are presented in Table 15. The PPE estimates, excluding the females sampled for fecundities, are 20,224 adult males and 20,463 adult females with 95% confidence limits of ± 3,502 (17.3%) and ± 4,464 (21.8%), respectively. The PPE estimate of the total escapement, produced by summing the sex-specific estimates, is 40,687 ± 5,674 (13.9%) adult sockeye. The age-specific estimates are based on the sex-specific age composition in the aged carcass sample (Table 4). The jack escapement could not be calculated because, although 1 jack was tagged, no jack carcasses were recovered in 1995 (Table 2).

Maximum-likelihood Darroch estimates were

Table 4. Percent at age and mean POH length at age in Seymour River sockeye sampled on the spawning grounds, 1995.

Recovery location	Sex	Percent at age					POH length (cm) at age				
		3_2	4_2	4_3	5_2	5_3	3_2	4_2	4_3	5_2	5_3
Seymour River	Male	-	92.6%	-	7.4%	-	-	49.4	-	55.0	-
	Female	-	91.1%	-	8.9%	-	-	47.8	-	53.8	-
	Jack [a]	-	-	-	-	-	-	-	-	-	-

[a] No jacks were sampled in 1995.

Table 5. Proportion of the Seymour River sockeye recoveries that were marked with disk tags and/or secondary marks, by recovery period and sex, in 1995, for the three stratifications used.

Recovery period	Number of surveys [a]	Marked carcasses recovered			Total Recovery			Mark incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Equal recovery periods										
22-Aug to 30-Aug [b]	4	2	0	0	74	35	0	2.7%	0.0%	-
31-Aug to 06-Sep	5	16	6	0	664	273	0	2.4%	2.2%	-
07-Sep to 13-Sep	4	75	53	0	2,782	2,768	0	2.7%	1.9%	-
14-Sep to 18-Sep	4	4	4	0	298	622	0	1.3%	0.6%	-
Similar recovery effort										
22-Aug to 31-Aug	5	2	0	0	111	49	0	1.8%	0.0%	-
01-Sep to 06-Sep	4	16	6	0	627	259	0	2.6%	2.3%	-
07-Sep to 12-Sep	4	68	42	0	2,547	2,293	0	2.7%	1.8%	-
13-Sep to 18-Sep	4	11	15	0	533	1,097	0	2.1%	1.4%	-
Similar total number of recoveries										
22-Aug to 07-Sep	10	23	6	0	925	388	0	2.5%	1.5%	-
08-Sep to 09-Sep	1	38	15	0	1,309	874	0	2.9%	1.7%	-
10-Sep to 12-Sep	2	25	27	0	1,051	1,339	0	2.4%	2.0%	-
13-Sep to 18-Sep	4	11	15	0	533	1,097	0	2.1%	1.4%	-

Chi-square test results

Stratification scheme	Males			Females		
	χ^2	df	*P*	χ^2	df	*P*
Equal recovery periods	2.05	3	0.56	5.92	3	0.12 [c]
Similar recovery effort	0.91	3	0.82	2.40	3	0.49 [c]
Similar total number of recoveries	1.31	3	0.73	1.58	3	0.66

[a] Based on recovery effort in areas 4 and 5.

[b] Regular surveys did not begin until 30-Aug.

[c] Test result inaccurate due to small sample size in some cells.

produced for male and female temporal and spatial data arrays (Table 15) which satisfied model assumptions (passed Plante's goodness-of-fit test). Selective pooling of strata (Table 13 and 14) was only required for female temporal and spatial data arrays. The MLE estimates differed from the PPE estimates by 20.0% (male) and –0.3% (female) for temporally stratified data, and -0.6% (male) and 1.5% (female) for spatially stratified data.

Although Schaefer estimates were produced at all stratification scales, the reported values are those produced at the same scale as the reported MLE estimate. All Schaefer estimates were larger, by less than 2%, than the corresponding PPE estimates.

The sex-specific PPE estimates are accepted, because the 95% confidence intervals of all four MLE estimates overlap those of the PPE estimates extensively, and the discrepancies between the MLE and PPE estimates are relatively small.

DISCUSSION

ASSUMPTIONS

The Petersen mark-recapture technique is based on the principle that, by tagging a random sample of fish, permitting them to redistribute through the population, and obtaining a second random sample of tagged and untagged individuals, the number of fish in the population can be

Table 6. Proportion of disk tagged sockeye recovered in the Seymour River, by application period and sex, in 1995, for the three stratifications used.

Application period	Number of sets	Disk tags applied[a]			Carcasses recovered with disk tags			Percent recovered		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Equal application periods										
19-Aug to 24-Aug	18	110.0	53.0	0	22	5	0	20.0%	9.4%	-
25-Aug to 29-Aug	17	279.6	199.4	0	61	44	0	21.8%	22.1%	-
30-Aug to 03-Sep	15	135.3	95.7	1	13	12	0	9.6%	12.5%	0.0%
04-Sep to 08-Sep	13	22.2	24.8	0	1	2	0	4.5%	8.1%	-
Similar application effort										
19-Aug to 23-Aug	15	87.8	37.2	0	16	2	0	18.2%	5.4%	-
24-Aug to 28-Aug	17	240.3	177.7	0	51	41	0	21.2%	23.1%	-
29-Aug to 02-Sep	15	182.7	120.3	1	29	18	0	15.9%	15.0%	0.0%
03-Sep to 08-Sep	16	36.3	37.7	0	1	2	0	2.8%	5.3%	-
Similar number of tags applied										
19-Aug to 25 Aug	21	143.4	80.6	0	28	13	0	19.5%	16.1%	-
26-Aug to 27-Aug	8	130.2	95.8	0	30	24	0	23.0%	25.1%	-
28-Aug to 30-Aug	9	164.6	101.4	0	29	15	0	17.6%	14.8%	-
31-Aug to 08-Sep	25	109.0	95.0	1	10	11	0	9.2%	11.6%	0.0%

Chi-square test results

Stratification scheme	Males			Females		
	χ^2	df	*P*	χ^2	df	*P*
Equal application periods	12.36	3	0.01*	8.57	3	0.04*
Similar application effort	8.05	3	0.04*	12.25	3	0.01*
Similar number of tags applied	8.31	3	0.04*	6.81	3	0.08

[a] Corrected for sex identification error.

estimated with known precision. The accuracy of an escapement estimate depends on how well the study meets the assumptions underlying the technique. These assumptions have been described in various forms by Ricker (1975), Otis *et al.* (1978), Eames *et al.* (1981), Seber (1982) and Arnason *et al.* (1996) and are discussed below in the context of the current study.

Population Closure

In a closed population the number of animals does not change during the study. The population did change during this study, through immigration, die-off and emigration; however, such factors will not violate the closure assumption if all components of the population are vulnerable to either marking and/or carcass recovery, and death and emigration affect marked and unmarked fish equally (Arnason *et al.* 1996). The current study achieved the former condition. Temporally, marking began when sockeye first entered the river and continued until the immigration was complete, and recovery began one day after the first marked sockeye were released and ended when low recovery rates indicated die-off was complete. Spatially, all fish were vulnerable to marking at one or more of the tagging sites, and all areas of the Seymour River system were included in recovery surveys.

Sockeye can become unavailable to recovery (emigrate from the study area) by several mechanisms, including carcass decomposition, predator activity and fishing, and flushing downstream. The former were likely unimportant to the current study because inter-survey periods averaged only two days, there was little predator activity and no fisheries in the study area. Further, it is unlikely that marked fish were disproportionately affected

Table 7. Proportion of the Seymour River sockeye recoveries that were marked with disk tags and/or secondary marks, by recovery section and sex, in 1995. McNomee Creek carcass recoveries are included here to illustrate spatial mark incidence patterns throughout the system; they were not used in the mark-recapture estimates.

	Marked carcasses recovered			Total Recovery			Mark incidence		
Recovery section [a]	Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Lakeshore	4	0	0	142	137	0	2.82%	0.00%	-
Lower Seymour	77	50	0	3,027	2,909	0	2.54%	1.72%	-
Upper Seymour	16	13	0	649	652	0	2.47%	1.99%	-
McNomee Creek	8	9	0	1,326	1,195	0	0.60%	0.75%	-

Chi-square test results

	Male			Female		
Test compares:	χ^2	df	*P*	χ^2	df	*P*
All sections:	18.55	3	0.00 **	8.75	3	0.03 *
All but McNomee Creek:	0.06	2	0.97	2.71	2	0.26
McNomee Creek versus other sections pooled:	17.52 [b]	1	0.00 **	4.99	1	0.03 *, [b]

[a] Section definitions: Lower Seymour- areas 4, 4a and 5; Upper Seymour- areas 1-3; Lakeshore - areas 5a and 5b.
[b] χ^2 values are Yates corrected.

Table 8. Proportion of disk tagged sockeye recovered in the Seymour River, by tag site location and sex, in 1995.

Tag site location	Number of sets	Disk tags applied [a]			Carcasses recovered with disk tags			Percent recovered		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Reach 2	15	66.6	41.4	0	22	7	0	33.0%	16.9%	-
Reach 4	24	335.2	231.8	0	57	43	0	17.0%	18.5%	-
Reach 5	24	145.4	99.6	1	18	13	0	12.4%	13.0%	0.0%
χ^2 value:		Males:	13.65			Females:	1.50			
P (df=2):			0.00 **				0.47			

[a] Corrected for sex identification error.

by these mechanisms. Conversely, a large number of carcasses probably flushed out of the system, and marked fish may have been more or less likely to flush out due to application selectivity and/or tagging stress. For example, both selectivity for fish that spawned in the lower areas of the Seymour River, and for fish with impaired swimming ability due to tagging stress, could have caused marked fish to flush out at higher rates than unmarked ones. In this study, care was taken to avoid application selectivity and tagging-induced stress. Based on the above, and our later evaluation of selectivity and stress, we conclude that the population closure assumption was not violated in this study.

Correct Identification of Tag Status

If uncorrected, misidentification of carcasses with a disk tag and/or secondary mark as unmarked results in an overestimate of escapement. Surveyor inexperience, fatigue or assigning a higher priority to recovery speed than to thoroughness can all contribute to this error. In the current study, a resurvey of 37% of the recovered carcasses showed that 1.1% of the disk tags present on the initial survey had been misidentified as unmarked. This error rate was low relative to many recent studies (Schubert 1998), including the previous Seymour River system study (1.7%; Schubert 1997). This difference may be due to

Table 9. Sex composition of Seymour River sockeye adults in the application and recovery samples, 1995.

	Application sample, by recovery status			Recovery sample, by mark status		
Sex	Disk tags applied[a]	Disk tags recovered	Percent recovered	Total recovery	Marked recoveries	Mark incidence
Male	547.2	97	17.7%	3,818	97	2.5%
Female	372.8	63	16.9%	3,698	63	1.7%
χ^2 value[b]:		Recovery bias test:	0.06		Application bias test:	5.92
P (df=1):			0.81			0.01 *

[a] Corrected for sex identification error.

[b] χ^2 values are Yates corrected.

Table 10. Proportion of disk tagged sockeye recovered in the Seymour River, by sex and 3 cm increments of nose-fork length, 1995.

Nose-fork length	Disk tags applied[a]			Carcasses recovered with disk tags			Percent recovered		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
51 - 53.9	1	4	5	0	1	1	0.0%	25.1%	20.0%
54 - 56.9	0	29	29	0	5	5	-	17.2%	17.2%
57 - 59.9	36	189	225	5	28	33	13.8%	14.8%	14.7%
60 - 62.9	221	113	334	40	24	64	18.1%	21.3%	19.2%
63 - 65.9	224	23	247	41	3	44	18.3%	13.1%	17.8%
66 - 68.9	42	15	57	5	2	7	11.8%	13.7%	12.3%
69 - 71.9	14	1	15	4	0	4	28.3%	0.0%	26.7%
72 - 74.9	8	0	8	2	0	2	24.8%	-	25.0%
Kolmogorov-Smirnov 2-sample test Dmax (continuous data; see text):							0.035	0.113	0.056
Kolmogorov-Smirnov 2-sample test Dcritical (α = 0.05):							0.150	0.185	0.116

[a] Corrected for sex identification error.

the implementation of recommendations made by Schubert (1997), including emphasizing to crews the importance of complete accuracy in identification of carcass tag status and more frequent resurveys allowing quicker feedback and retraining to staff who are missing tags. These procedures should continue; however, the complete elimination of errors may be unattainable at realistic levels of survey effort.

The estimated number of missed tags is likely reasonably accurate, and more accurate than previous studies due to procedural changes implemented in 1995. The resurveys were more frequent and spatially more representative, and examined a larger proportion of the carcasses. Furthermore, all of the initially surveyed carcasses were unambiguously marked (chopped in two behind the dorsal fin), thereby ensuring that carcasses deposited by predators or high water were not included in the resurvey. Unfortunately, the only available method for incorporating the variance of the missed tag estimate into the population variance (Rajwani and Schwarz 1997) was not applicable to this study, because carcasses identified as tagged on the initial survey were included in the resurvey. The precision of the population estimates, therefore, is overestimated (*i.e.*, the 95% confidence intervals reported are too small). In future studies, carcasses identified on the recovery survey as marked should be excluded from the resurvey, so that the variance estimation procedures of Rajwani and Schwarz (1997) can be applied. This can be easily achieved either by making such carcasses identifiable (*e.g.*, by chopping them in three, with chops in front and behind the dorsal fin) or by throwing them far up the bank.

Table 11. Comparison of mark (disk tag and/or secondary mark) incidence in the recovery sample and in the carcass seining sample. The entire seining sample was taken from a deep pool in Area 2. χ^2 tests compare tagged: untagged ratios in the seining and standard samples, for three scales of standard sample.

Recovery sample	Recovery dates	Marked carcasses recovered			Total recovery			Mark incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Seining	10 & 12-Sep	1	2	0	56	170	0	1.79%	1.18%	-
Standard:										
(1) Area 2	10 to 12-Sep	8	10	0	281	338	0	2.85%	2.96%	-
(2) Area 2	All	11	12	0	531	541	0	2.07%	2.22%	-
(3) All areas	All	97	63	0	3,818	3,698	0	2.54%	1.70%	-

Chi-square test results

Test compares:	Males			Females		
	$\chi^{2\,a}$	df	*P*	$\chi^{2\,a}$	df	*P*
Seining vs 1	0.00	1	1.00 [b]	0.88	1	0.35
Seining vs 2	0.12	1	0.73 [b]	0.29	1	0.59
Seining vs 3	0.01	1	0.94 [b]	0.05	1	0.83

[a] χ^2 values are Yates corrected.

[b] Test result inaccurate due to small sample size in some cells.

No Undetected Tag Loss

Undetected loss of disk tags between application and recovery results in an underestimate of the proportion of the population with tags and an overestimate of escapement. Tag loss can result from poor tag application technique, tangling of the tag in the net after release, or the fighting which is common among males during spawning. In the current study, tag loss was assessed by applying an opercular punch as a permanent secondary mark. No tag loss was detected. This value probably underestimates true tag loss, for two reasons. First, opercular punch holes could effectively be lost, since they could be distorted and enlarged by fungus, decomposition and predator activity, making carcasses with missing disk tags indistinguishable from untagged carcasses with holes in their opercula. Second, the surveyors could have missed non-disfigured opercular punches on carcasses that had lost disk tags. No estimate of this error was possible because disk tags, but not secondary marks, were removed during the initial surveys. In future studies, the incidence of missed secondary marks can be determined if carcasses identified as disk tagged and/or secondary marked are excluded from the resurvey. Further, alternate secondary marks should be evaluated and available for use should the detection of opercular punches prove inadequate.

Equal Catchability

Recovery probabilities across strata (hereafter, 'average' recovery probabilities) of marked and unmarked sockeye must be equal for the PPE estimate to be unbiased. For stratified models to be unbiased, average recovery probabilities of these two groups can differ, but recovery probabilities within strata must be equal (Arnason *et al.* 1996). Note that even when recovery probabilities are equal within each stratum, unequal average recovery probabilities can exist unless one or more of the following three conditions exist: i) proportional application, ii) proportional recovery, and iii) complete mixing. If recovery probabilities differ within strata, average recovery probabilities will rarely be equal.

Tagging stress effects and selective application sampling can both influence where and when tagged carcasses become recoverable, potentially causing unequal recovery probabilities of tagged and untagged fish. Stress can influence the distance and duration of movements by impairing swimming ability and causing earlier death; application can favour fish with specific spawning ground distributions or spawning schedules.

Table 12. Bias profile for the 1995 Seymour River sockeye escapement estimation study.

Bias type	Test of	Between	Test result [a]
Application sample			
Temporal	Tagged: untagged recoveries	Equal recovery periods	No bias
		Periods of similar recovery effort	No bias
		Periods of similar total recoveries	No bias
Spatial	Tagged: untagged recoveries	Three recovery sections	No bias [b]
Fish sex	Tagged: untagged recoveries	Sexes	Male bias
Recoverability	Tagged: untagged recoveries	Seined vs normal recoveries	No bias
Stress	Recovery of a tag less than 5 days after release:	-	Removed 2 disk tags
	Recovered: unrecovered tags	Application methods	No bias
	Recovered: unrecovered tags	Release condition 1 vs 2-3 [c]	No bias
	Recovered: unrecovered tags	Recaptured vs not recaptured	No bias
	Spawning success:	Tagged: untagged recoveries	No bias
Recovery sample			
Statistical	Minimum recovery of 5 tags:	-	No bias
Temporal	Recovered: unrecovered tags	Equal application periods	Early bias
		Periods of similar application effort	Early bias
		Periods of similar applications	Early bias (males)
Spatial	Recovered: unrecovered tags	Three application sites	Upper river bias (males)
Fish sex	Recovered: unrecovered tags	Sexes	No bias
Fish size	Size-frequency distrib:	Recovered: unrecovered tags	No bias

[a] A "no bias" test result indicates that bias was not detected; undetected bias may be present.

[b] McNomee Creek had a significantlly lower tag incidence than the Seymour River, in both sexes.

[c] See text for description of release conditions.

While the application bias tests should detect such differences, they do not distinguish their cause. Application bias will not induce unequal recovery probabilities of marked and unmarked fish, however, if the recovery sample is unbiased or has an independent source of bias (Junge 1963; Seber 1982).

In the current study, tag application was designed to minimize tagging stress (see above). Only 6 (0.7%) fish did not swim away vigorously upon release, suggesting that application was reasonably stress-free. As well, tagged fish were excluded from the analysis if there were indications that they were stressed by application. Two fish recovered less than five days after tagging were excluded, because of the likelihood that they suffered acute stress. Because the proportion of tagged fish recovered was not affected by any of the three stress factors examined, fish in the (potentially) high-stress groups were retained. These procedures, however, probably did not fully eliminate the influence of tagging stress on tagged fish.

The sampling methods were also designed to minimize selectivity, through proportional application and recovery. To achieve application proportionality, fish were captured using a gear known to minimize selectivity, and a standardized daily tagging effort was applied throughout the run. Expending application effort evenly may not achieve proportional application, however, due to variability in river conditions, the proportion of the fish which migrate at night, daily set times, the technique used during each set and the daily size of the migration (large migrations may exceed the tagging capacity of the crew). Also, fish migrating at night

Table 13. Temporally stratified tag application-recovery matrices, for the Seymour River, 1995. The finest scale stratifications (see text) are shown; bracketed strata were aggregated to produce an ML Darroch estimate and attempt to meet the assumptions of the ML Darroch model. Male data are not whole numbers due to correction for missed tag error.

Male

		Recovery period				
Application period	Tags applied	22-Aug to 7-Sep	8-Sep to 9-Sep	10-Sep to 12-Sep	13-Sep to 18-Sep	Total recovered
19-Aug to 25-Aug	138.7	13.3	13.3	1.0	1.0	28.6
26-Aug to 27-Aug	126.0	7.2	13.3	5.1	5.1	30.7
28-Aug to 30-Aug	159.3	3.1	11.2	13.3	2.0	29.7
31-Aug to 08-Sep	105.5	0.0	1.0	6.1	3.1	10.2
Total tags:	529.6	23.5	38.9	25.6	11.2	99.2
Total recovered:		925	1,309	1,051	533	3,818

Female

		Recovery period				
Application period	Tags applied	22-Aug to 7-Sep	8-Sep to 9-Sep	10-Sep to 12-Sep	13-Sep to 18-Sep	Total recovered
[19-Aug to 25-Aug]	76.4	5	3	3	2	13
[26-Aug to 27-Aug]	90.7	0	8	11	5	24
[28-Aug to 30-Aug]	96.1	1	3	7	4	15
[31-Aug to 08-Sep]	89.9	0	1	6	4	11
Total tags:	353.1	6	15	27	15	63
Total recovered:		388	874	1,339	1,097	3,698

(and other periods of the day in which application did not occur) may have differed in behavior, sex ratio, size distribution and/or other aspects, leading to application selectivity for these attributes. Similarly, although the recovery survey effort was applied relatively equally (spatially and temporally) throughout the die-off, sample selectivity may have persisted for a variety of reasons, including variable river conditions.

Here, evidence regarding the likelihood that recovery probabilities of tagged and untagged sockeye were equal (at either level) in this study is examined. First, the pool recoveries provide a direct comparison of the recovery probability (in standard recovery) of marked and unmarked carcasses, because they are sampled from the typically large component of the population that was not catchable by standard recovery methods. The tag incidence did not differ between the pool and standard recoveries, indicating similar recovery probabilities of marked and unmarked carcasses. Unfortunately, this test is weak, since the seine sample was relatively small and unrepresentative both spatially and temporally. Future studies should strive to collect a larger and more representative sample of carcasses in pools to provide a more powerful test of this assumption, and to allow stratification by recovery type for cases in which tag incidences differ. Tagging stress is the most likely cause of different tag incidences in standard versus pool recoveries because it may cause tagged fish to spawn in lower velocity, nearshore areas. The similar tag incidence in the two samples, therefore, provides weak support for the conclusion that application procedures were effectively stress-free.

Second, there was no influence of tag status on female spawning success. This indicates that the behavior of tagged and untagged fish was similar, increasing the likelihood that the two groups had similar recovery probabilities. This result also suggests that tagging procedures were relatively unstressful, because spawning success is known to be sensitive to stress in salmon (Schubert *et al.* 1994).

Table 14. Spatially stratified tag application-recovery matrices, for the Seymour River, 1995. The finest scale stratifications (see text) are shown; bracketed strata were aggregated to produce an ML Darroch estimate and attempt to meet the assumptions of the ML Darroch model. Male data are not whole numbers due to correction for missed tag error.

Male

		Recovery section[a]			
Tag site location	Tags applied	Lakeshore	Lower Seymour	Upper Seymour	Total recovered
Area 2	64.5	0.0	12.3	10.2	22.5
Area 4	324.4	1.0	51.1	6.1	58.3
Area 5	140.7	3.1	15.3	0.0	18.4
Total tags:	529.6	4.1	78.7	16.4	99.2
Total recovered:		142	3,027	649	3,818

Female

		Recovery section[a]			
Tag site location	Tags applied	[Lakeshore	Lower Seymour]	Upper Seymour	Total recovered
Area 2	39.2	0	0	7	7
Area 4	219.5	0	37	6	43
Area 5	94.3	0	13	0	13
Total tags:	353.1	0	50	13	63
Total recovered:		137	2,909	652	3,698

[a] Recovery section definitions: Lakeshore- areas 5a and 5b; Lower Seymour- areas 4, 4a and 5; Upper Seymour- areas 1- 3.

Finally, the bias tests detected three types of bias: i) an application bias toward males, ii) a temporal recovery bias in both sexes, and iii) a spatial recovery bias in males (Table 12). Thus, at least one of the two samples (application or recovery) was proportional with respect to size, sex, time and space, and these factors should, therefore, not have produced unequal recovery probabilities.

Note, however, that nonsignificant results of bias tests ($p>0.05$) do not prove that no bias exists. For example, the power of some or all of the bias tests may be low, and the stratification used in a bias test may 'hide' an actual bias. Therefore, separate estimates were calculated for males and females. Further, PPE estimates were compared with estimates produced by stratified models with temporally and spatially stratified data, to determine whether temporal and spatial biases influenced the estimates substantially.

GENERAL DISCUSSION

The design of future studies should be modified, if possible, to avoid the temporal and spatial biases encountered in this study. Here, possible causes of these biases are examined, and corresponding solutions are suggested. The temporal bias in recovery involved decreasing tag recovery rates with application date for both sexes. This bias is not an artefact, since it appeared in all three stratification schemes. Changing river conditions through the recovery may have caused this trend. Early in the recovery, (Aug. 28 to Sept. 1) water clarity was described as 'excellent' for recovery (Wyett, pers. comm.). Near the midpoint of the recovery, the water level rose and visibility dropped to 0.5m, apparently due to a heavy rain on Sept. 6. As well, tagging continued seven days longer at the lower river tagging sites than at the upper site. This would result in a larger proportion of fish tagged later to flush out of the system if fish tagged in the lower river tended to spawn and die there, as indicated by the spatially stratified recovery data (Table 14).

Second, male sockeye tagged in the lowest area (Area 5) experienced the lowest recovery rates, while those tagged in the upper river (Area 2) experienced the highest; these differences were significant, indicating a spatial recovery

Table 15. Escapement estimates and 95% confidence limits, by age and sex, for Seymour River sockeye, 1995. Asterisks indicate accepted estimates.

		Escapement at age [a]						95% confidence limits on total	
Estimator	Sex	3_2	4_2	4_3	5_2	5_3	Total	Lower	Upper
Pooled	Male	0	18,730	0	1,494	0	20,224 *	16,722 *	23,726 *
Petersen	Female	0	18,634	0	1,829	0	20,463 *	15,999 *	24,927 *
	Total [b]	0	37,364	0	3,323	0	40,687 *	35,013 *	46,361 *
	Total [c]	0	37,378	0	3,325	0	40,703	35,142	46,263
	Jack	-	-	-	-	-	0 *	-	-
Application and recovery stratified temporally									
ML	Male [d, e]	-	-	-	-	-	24,264	12,665	35,863
Darroch	Female [d, e]	-	-	-	-	-	20,402	13,889	26,915
Schaefer	Male [e]	-	-	-	-	-	20,598	-	-
	Female [e]	-	-	-	-	-	20,704	-	-
Application and recovery stratified spatially									
ML	Male [d, e]	-	-	-	-	-	20,109	15,856	24,363
Darroch	Female [d, e]	-	-	-	-	-	20,779	16,129	25,430
Schaefer	Male [e]	-	-	-	-	-	20,327	-	-
	Female [e]	-	-	-	-	-	20,757	-	-

[a] Excludes 25 females which were killed for fecundity samples.

[b] Sum of male and female estimates. Confidence intervals calculated as in Schubert (1997).

[c] Estimated from pooled data.

[d] Model assumptions are satisfied (passes Plante's goodness-of-fit test (Arnason *et al.* 1996)).

[e] Stratifications used to produce estimates are indicated in Tables 13 and 14.

bias. In females, recovery rates of those tagged in Area 5 were similarly low, although not significantly different from those tagged at the other sites. Fish tagged in Area 5 would experience a lower recovery rate if they spawned (on average) closer to the lake, and thus flushed-out and became unrecoverable at a greater rate. Such a spawning distribution is suggested by the spatially stratified recovery data (Table 14). This mechanism may not have produced as great a difference in recovery rates in females because they typically defend the redd for several days after spawning, unlike males who often 'drift' downstream after spawning. Future studies should use procedures designed to ensure that fish tagged in Area 5 have not already begun spawning. Thus, alternative tagging sites where less spawning fish will be caught should be used (if available), and tagging crews should be more discriminating when deciding to reject a fish because it is thought to have begun spawning.

Carcasses were recovered from McNomee Creek on the same survey cycle as used on the Seymour River. Mark recapture data, therefore, could have been used to estimate the spawning sockeye population in the entire watershed. The analytical approach used, in which the population estimated by mark recapture was limited to the Seymour River by adjusting the tags applied data to exclude the estimated number of tagged sockeye that migrated to McNomee Creek, was dictated by spatial biases in McNomee Creek relative to the Seymour River. First, tag incidence in McNomee Creek was significantly lower than in the Seymour River (Table 7). Second, recovery rates in McNomee Creek were significantly higher ($p<0.001$, chi-square, 1 df); 31.3% of the estimated 8,059 spawning sockeye in McNomee Creek (Schubert 2000) versus 18.5% of the estimated 40,687 spawning sockeye in the Seymour River. The higher recovery rate in McNomee Creek probably resulted from the smaller volume

of the creek, making a larger fraction of carcasses accessible. If the population estimated by mark recapture had not been limited to the Seymour River, these two spatial biases would have caused the estimate to be positively biased.

In the current study, tagged sockeye migrating to McNomee Creek were estimated from a live count-based population estimate. Such estimates are likely quite inaccurate. In future studies, McNomee Creek escapement should be estimated with an enumeration fence if possible. This would improve both the McNomee Creek estimate and the mark recapture estimate of the Seymour River, because the number of tagged sockeye migrating to McNomee Creek will be known accurately. If this solution is unavailable, some tagging should be conducted near the mouth of McNomee Creek in an attempt to increase tag incidence in there; if the spatial application bias can be eliminated, a watershed-wide mark recapture estimate can be calculated.

Past studies have generated a mark recapture estimate of the spawning sockeye population in the entire watershed, although both of these spatial biases were present (*e.g.*, 1994; Schubert 1997). For those studies, the current approach of limiting the mark recapture population to the Seymour River would have been insufficient to deal with spatial bias, because similar biases were present in the upper Seymour River (relative to the lower river). In those studies, tagging was limited to the lower river resulting in a relatively low tag incidence in the upper Seymour River. As well, upper river spawners probably tended to have higher recovery rates than those in the lower river, as indicated by recovery rates of fish tagged in the upper versus the lower parts of the river in this study (Table 8). Because no independent estimate of the upper Seymour River population was available, this population could not be excluded from the population estimated by mark recapture. Notice that the upper river tagging site was added in 1995 to eliminate the difference in tag incidence between the lower and upper Seymour River; this approach was successful and should be continued in future studies.

RECOMMENDATIONS

The 1995 study was similar to the 1994 study but included modifications designed to reduce sample selectivity and to facilitate assessment of tag loss and the effects of sub-acute and acute stress. Future studies should build on the 1995 study design, with the following modifications:

1. The following changes should be considered to reduce sampling bias:

- continue tagging efforts at all application sites until the same date to reduce the temporal recovery bias;
- use an enumeration fence in McNomee Creek, or add a tagging site near the mouth of McNomee Creek to increase the tag incidence in that tributary and reduce the spatial application bias;
- consider alternative tagging sites or capture procedures in Area 5 to reduce the apparent selectivity toward local spawners, and reduce the spatial recovery bias and potentially reduce temporal recovery bias as well.

2. The following changes will provide data that will help test important assumptions of the model:

- in areas with tag sites, records should distinguish carcass recoveries above and below the tagging site. For areas with several tagging sites, records should identify three recovery locations: i) below the furthest downstream site, ii) above the furthest upstream site and iii) the remainder of the area. This minor change will allow more extensive testing to ensure that tagging stress (or potentially, but less likely, application selectivity) is not severe enough to affect the distribution and mortality schedules of tagged fish;
- a carcass weir (or gaffing or dip netting of carcasses) at the river mouth would allow comparison of the 'emigration' rate of tagged and untagged carcasses. These samples, distributed over the period of die-off, would provide a test for population closure. These methods are effective at the mouth of the Seymour River (Wyett, pers. comm.);
- recovery of carcasses from pools allows testing of the assumption that tagged and untagged carcasses are equally likely to be recovered during normal shore oriented surveys. To make this test more representative (and powerful) than in 1995, pool should be sampled across the die-off (once several days before and after, as well as on, peak die-off) in several of the more important recovery areas (area 2, 4, and 5, and McNomee Creek). Such recoveries should be made by the most appropriate means for each site; possible methods include carcass seining and gaffing from shore or tethered boat. Wyett (pers. comm.) suggests that gaffing from shore should be quite effective in many areas of the Seymour River system.

3. To allow for incorporation of the uncertainty in the misidentification error rate into population estimates (Rajwani and Schwarz 1997), carcasses identified as disk tagged and/or secondary marked on the recovery survey should be excluded from the resurvey, by chopping them in three (with chops in front and behind the dorsal fin). This change will also enable an estimation of the rate at which carcasses which had lost a disk tag but retained a secondary mark were misidentified as unmarked on the initial survey.

4. The rate of sex-identification errors is estimated from the recovery sample (only a subsample of the application sample). The uncertainty in this estimate contributes to the uncertainty in the population estimates; currently, this contribution is unaccounted for. As recommended by Schubert (1997), analytical methods should be developed to allow for the variance in these error rate estimates to be incorporated into the variance of the population estimates.

ACKNOWLEDGEMENTS

Tim Ewanyshyn, Mike Moss, Tony Rathbone, and Jake Wideman conducted field activities under the supervision of Ken Peters and Bill Wyett. Tracy Cone supervised data entry and verification. Aswea Porter and Joe Tadey provided a preliminary analysis of the study data. The maps were drafted by XY3 Graphics. The final draft of this report was improved by review comments provided by Al Cass, Rob Kronlund and Timber Whitehouse.

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APPENDICES

Appendix 1a. Sockeye jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the Seymour River system, 1938-1995.

Year	Escapement				Percent spawning success	Effective females
	Total	Jacks	Males	Females		
1938	0	0	0	0	-	0
1939	250	0	125	125	95.0%	119
1940	0	0	0	0	-	0
1941	0	0	0	0	-	0
1942	2,412	0	1,034	1,378	95.0%	1,309
1943	67	0	35	32	95.0%	30
1944	200	0	100	100	95.0%	95
1945	0	0	0	0	-	0
1946	3,778	0	1,814	1,964	95.0%	1,866
1947	19,795	0	11,160	8,635	100.0%	8,635
1948	4,099	210	2,609	1,280	100.0%	1,280
1949	10,772	0	7,273	3,499	99.3%	3,476
1950	12,471	1,422	5,999	5,050	93.0%	4,697
1951	24,344	24	12,026	12,294	93.6%	11,505
1952	6,428	465	2,921	3,042	91.4%	2,780
1953	5,947	255	2,599	3,093	94.0%	2,907
1954	24,876	102	11,595	13,179	97.5%	12,852
1955	9,011 [a]	40	3,677	5,294	97.8%	5,178
1956	2,562	72	1,367	1,123	97.1%	1,090
1957	14,295 [a]	3,425	3,279	7,591	97.7%	7,416
1958	78,578	207	33,684	44,687	99.1%	44,285
1959	52,325 [a]	15	26,511	25,799	99.9%	25,773
1960	3,047	146	1,039	1,862	100.0%	1,862
1961	5,822	2,200	1,492	2,130	91.9%	1,957
1962	58,104 [a]	268	24,583	33,253	86.2%	28,664
1963	71,690 [b]	36	33,287	38,367	69.7%	26,742
1964	2,784 [b]	39	1,408	1,337	98.8%	1,321
1965	6,954 [b]	865	3,341	2,748	92.8%	2,550
1966	28,754 [b]	56	14,349	14,349	90.2%	12,943
1967	13,361 [b]	0	5,600	7,761	93.6%	7,264
1968	3,957	119	1,696	2,142	96.4%	2,064
1969	7,327 [b]	151	3,576	3,600	91.0%	3,276
1970	11,991 [b]	20	6,704	5,267	68.4%	3,603
1971	19,028 [b]	0	8,641	10,387	91.1%	9,463
1972	2,889	87	1,358	1,444	98.2%	1,418
1973	2,856 [b]	152	1,539	1,165	98.7%	1,150
1974	45,189 [a,b]	601	18,459	26,129	99.0%	25,868
1975	37,024 [a,b]	196	19,865	16,963	99.3%	16,844
1976	8,489	183	3,387	4,919	99.6%	4,898
1977	5,911	202	2,696	3,013	95.7%	2,883
1978	62,929 [b]	121	31,955	30,853	99.7%	30,757
1979	49,321 [b]	15	23,834	25,472	97.6%	24,866
1980	8,390	81	3,531	4,778	96.6%	4,616

Continued

Appendix 1a. Sockeye jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the Seymour River system, 1938-1995.

Year	Escapement				Percent spawning success	Effective females
	Total	Jacks	Males	Females		
Continued						
1981	11,529	170	5,934	5,425	98.7%	5,354
1982	63,306 [b]	35	35,785	27,486	99.0%	27,219
1983	29,838 [b]	7	15,667	14,164	98.9%	14,014
1984	17,172	0	8,024	9,148	100.0%	9,148
1985	6,435	815	2,936	2,684	100.0%	2,684
1986	128,497 [a,b]	2,331	68,439	57,727	98.9%	57,069
1987	84,409 [b]	94	40,843	43,472	94.5%	41,081
1988	17,014 [a,b]	233	8,641	8,140	98.2%	7,989
1989	5,692	185	2,643	2,864	100.0%	2,864
1990	272,157 [b]	116	162,746	109,295	99.1%	108,279
1991	128,253 [b]	0	66,793	61,460	99.0%	60,845
1992	5,765	23	2,156	3,586	100.0%	3,586
1993	10,206	87	5,169	4,950	100.0%	4,950
1994	64,038 [b]	0	44,699	19,339	99.0%	19,152
1995	48,746 [b]	0	24,463	24,283	98.5%	23,915

[a] Includes fish taken for brood stock or other samples.

[b] Estimated by a mark-recapture study.

Appendix 1b. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which had spawned effectively in the Seymour River, 1938-1995.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1938	-	-	0	0	0	0	-	0
1939	-	-	250	0	125	125	95.0%	119
1940	-	-	0	0	0	0	-	0
1941	-	-	0	0	0	0	-	0
1942	10-Sep	19-Sep to 22-Sep	2,412	0	1,034	1,378	95.0%	1,309
1943	25-Aug	04-Sep to 10-Sep	67	0	35	32	95.0%	30
1944	-	-	200	0	100	100	95.0%	95
1945	-	-	0	0	0	0	-	0
1946	24-Aug	04-Sep to 10-Sep	3,778	0	1,814	1,964	95.0%	1,866
1947	12-Aug	04-Sep to 10-Sep	19,795	0	11,160	8,635	100.0%	8,635
1948	20-Aug	04-Sep to 10-Sep	4,099	210	2,609	1,280	100.0%	1,280
1949	11-Aug	20-Aug	10,772	0	7,273	3,499	99.3%	3,476
1950	10-Aug	24-Aug to 05-Sep	12,471	1,422	5,999	5,050	93.0%	4,697
1951	10-Aug	22-Aug to 25-Aug	24,344	24	12,026	12,294	93.6%	11,504
1952	11-Aug	19-Aug to 21-Aug	6,428	465	2,921	3,042	91.4%	2,780
1953	10-Aug	25-Aug to 26-Aug	5,947	255	2,599	3,093	94.0%	2,907
1954	a	a	24,876	102	11,595	13,179	97.5%	12,463
1955	16-Aug	26-Aug to 30-Aug	9,011[c]	40	3,677	5,294	97.8%	5,178
1956	11-Aug	25-Aug to 27-Aug	2,562	72	1,367	1,123	97.1%	1,102
1957	15-Aug	b	14,295[c]	3,425	3,279	7,591	97.7%	7,106
1958	9-Aug	07-Sep to 10-Sep	78,578	207	33,684	44,687	99.1%	44,285
1959	15-Aug	29-Aug to 03-Sep	52,325[c]	15	26,511	25,799	99.9%	25,473
1960	10-Aug	25-Aug to 02-Sep	3,047	146	1,039	1,862	100.0%	1,862
1961	22-Aug	31-Aug to 02-Sep	5,822	2,200	1,492	2,130	91.9%	1,957
1962	10-Aug	02-Sep to 04-Sep	58,104[c]	268	24,583	33,253	86.2%	27,411
1963	7-Aug	25-Aug to 29-Aug	71,690[d]	36	33,287	38,367	69.7%	26,742
1964	15-Aug	04-Sep to 06-Sep	2,784[d]	39	1,408	1,337	98.8%	1,321
1965	18-Aug	27-Aug to 28-Aug	6,954[d]	865	3,341	2,748	92.8%	2,550
1966	16-Aug	26-Aug to 31-Aug	28,754[d]	56	14,349	14,349	90.2%	12,943
1967	12-Aug	01-Sep to 04-Sep	13,361[d]	0	5,600	7,761	93.6%	7,264
1968	12-Aug	25-Aug to 28-Aug	3,957	119	1,696	2,142	96.4%	2,064
1969	10-Aug	20-Aug to 28-Aug	7,327[d]	151	3,576	3,600	91.0%	3,276
1970	17-Aug	06-Sep to 10-Sep	11,991[d]	20	6,704	5,267	68.4%	3,603
1971	14-Aug	03-Sep to 05-Sep	19,028[d]	0	8,641	10,387	91.1%	9,463
1972	12-Aug	02-Sep to 04-Sep	2,889	87	1,358	1,444	98.2%	1,418
1973	15-Aug	26-Aug to 30-Aug	2,856[d]	152	1,539	1,165	98.7%	1,150
1974	15-Aug	28-Aug to 02-Sep	45,189[c,d]	601	18,459	26,129	99.0%	25,096
1975	-	28-Aug to 01-Sep	37,024[c,d]	196	19,865	16,963	99.3%	15,756
1976	18-Aug	03-Sep to 05-Sep	8,489	183	3,387	4,919	99.6%	4,898
1977	15-Aug	28-Aug to 03-Sep	5,911	202	2,696	3,013	95.7%	2,883
1978	13-Aug	01-Sep to 05-Sep	62,929[d]	121	31,955	30,853	99.7%	30,757
1979	-	28-Aug to 05-Sep	49,321[d]	15	23,834	25,472	97.6%	24,866
1980	-	30-Aug to 02-Sep	8,390	81	3,531	4,778	96.6%	4,616

Continued

Appendix 1b. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which had spawned effectively in the Seymour River, 1938-1995.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
Continued								
1981	-	28-Aug to 02-Sep	11,529	170	5,934	5,425	98.7%	5,354
1982	-	09-Sep to 13-Sep	63,306[d]	35	35,785	27,486	99.0%	27,219
1983	-	30-Aug to 06-Sep	29,838[d]	7	15,667	14,164	98.9%	14,014
1984	-	29-Aug to 03-Sep	17,172	0	8,024	9,148	100.0%	9,148
1985	-	02-Sep to 05-Sep	6,435	815	2,936	2,684	100.0%	2,684
1986	-	05-Sep to 09-Sep	128,497[c,d]	2,331	68,439	57,727	98.9%	57,017
1987	-	05-Sep to 09-Sep	84,409[d]	94	40,843	43,472	94.5%	41,080
1988	-	30-Aug to 03-Sep	17,014[c,d]	233	8,641	8,140	98.2%	7,973
1989	-	31-Aug to 05-Sep	5,692	185	2,643	2,864	100.0%	2,864
1990	-	29-Aug to 05-Sep	272,157[d]	116	162,746	109,295	99.1%	108,234
1991	-	31-Aug to 08-Sep	128,253[d]	0	66,793	61,460	99.0%	60,797
1992	-	28-Aug to 04-Sep	5,765	23	2,156	3,586	100.0%	3,586
1993	-	31-Aug to 07-Sep	10,201	87	5,166	4,948	100.0%	4,948
1994	Mid Aug	30-Aug to 03-Sep	56,192[d]	0	39,222	16,970	98.9%	16,783
1995	19-Aug	25-Aug to 01-Sep	40,687	0	20,224	20,463	98.3%	20,105

a. Two arrival peaks, on 12-Aug and 22-Aug, and two spawning peaks, 24-Aug to 25-Aug and 01-Sep to 04-Sep.
b. Two spawning peaks, 25-Aug to 28-Aug and 30-Aug to 03-Sep.
c. Includes fish taken for brood stock or other samples.
d. Estimated by a mark-recapture study.

Appendix 1c. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which had spawned effectively in McNomee Creek, 1986-1995.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1986	-	-	a	a	a	a	-	a
1987	-	-	a	a	a	a	-	a
1988	-	-	a	a	a	a	-	a
1989	-	-	a	a	a	a	-	a
1990	-	-	a	a	a	a	-	a
1991	-	-	a	a	a	a	-	a
1992	-	-	a	a	a	a	-	a
1993	-	31-Aug to 07-Sep	5	0	3	2	100.0%	2
1994	-	30-Aug to 10-Sep	7,846	0	5,477	2,369	100.0%	2,369
1995	-	28-Aug to 05-Sep	8,059	0	4,239	3,820	99.7%	3,810

a. Included in Seymour River estimate.

Appendix 2. Counts of live sockeye salmon, by date and area, in the Seymour River, 1995.

	Recovery area						
Date	1	2	3	4	4a	5	Total
21-Aug	407	553	281	1,109	131	498	2,979
25-Aug	1,010	4,290	2,120	6,530 [a]	1,345	3,370	18,665
28-Aug	1,611	7,060	2,285	9,930	1,530	6,062	28,478
1-Sep	1,082	6,730	1,060	11,140	2,140	1,300	23,452
Distribution at peak:	6%	25%	8%	35%	5%	21%	

[a] Partial count; area from tagging site up to top of reach not counted.

Appendix 3. Number of sockeye salmon marked, and the number of recaptures of previously tagged sockeye, by date, location and sex, in the Seymour River, 1995. Values are not corrected for sex identification errors.

Date	Tagging site (area)	Number of sets	Sockeye marked			Recaptures		
			Male	Female	Jack	Male	Female	Jack
19-Aug	2	1	0	0	0	0	0	0
	4	1	0	0	0	0	0	0
	5	1	0	0	0	0	0	0
20-Aug	2	1	0	0	0	0	0	0
	4	1	6	3	0	1	1	0
	5	1	11	6	0	0	0	0
21-Aug	2	1	0	0	0	0	0	0
	4	1	18[1a]	12[3a]	0	0	0	0
	5	1	7	4	0	1	1	0
22-Aug	2	1	0	0	0	0	0	0
	4	1	21	5	0	1	1	0
	5	1	0	0	0	0	0	0
23-Aug	2	1	1	0	0	0	0	0
	4	1	23	8[1a]	0	1	0	0
	5	1	0	0	0	0	0	0
24-Aug	2	1	1	1	0	0	0	0
	4	1	10	7	0	1	0	0
	5	1	11[1a]	8	0	4	4	0
25-Aug	2	1	3	0	0	1	0	0
	4	1	23	21	0	5	1	0
	5	1	7	7	0	2	3	0
26-Aug	2	1	4	4	0	0	0	0
	4	1	40	34[1a]	0	3	0	0
	5	1	8	2	0	0	0	0
27-Aug	2	2	18	19	0	0	0	0
	4	1	31[1a]	24[1a]	0	2	1	0
	5	2	28	14[1a]	0	1	1	0
28-Aug	2	1	0	1	0	0	0	0
	4	1	44[2a]	36[1a]	0	2	1	0
	5	1	10[1a]	2	0	1	0	0
29-Aug	2	2	35	17[1a]	0	0	0	0
	4	1	26	21[1a]	0	4	4	0
30-Aug	2	1	1	0	0	0	0	0
	4	1	19[1b]	15	0	7	5	0
	5	1	29	11	0	0	0	0
31-Aug	4	3	28	10	0	0	0	0
	5	2	8	18	1	0	0	0
1-Sep	2	1	3	0	0	0	0	0
	4	1	17	18	0	0	0	0
2-Sep	4	2	16[1a]	12	0	0	1	0
3-Sep	5	3	14	13	0	3	2	0
4-Sep	4	2	3	5	0	0	0	0
	5	2	6	8	0	0	0	0
5-Sep	4	3	7	5[1b]	0	0	0	0
	5	1	1	1	0	0	0	0

Continued

Appendix 3. Number of sockeye salmon marked, and the number of recaptures of previously tagged sockeye, by date, location and sex, in the Seymour River, 1995. Values are not corrected for sex identification errors.

Date	Tagging site (area)	Number of sets	Sockeye marked			Recaptures		
			Male	Female	Jack	Male	Female	Jack
Continued								
6-Sep	4	1	1	0	0	0	0	0
	5	2	2	5	0	0	0	0
7-Sep	5	1	0	1	0	0	1	0
8-Sep	5	1	2	1	0	0	0	0
Total	2	15	66	42[1a]	0	1	0	0
	4	24	333[5a, 1b]	236[8a, 1b]	0	27	15	0
	5	24	144[2a]	101[1a]	1	12	12	0
	Total	63	543[7a, 1b]	379[10a, 1b]	1	40	27	0

[a] Excludes fish recovered in McNomee Creek.

[b] Includes fish recovered less than 5 days after release.

Numbers preceding notes indicate the number of fish to which notes apply.

Appendix 4a. Incidence of net, lamprey and hook marks and of *Flexibacter columnaris* lesions among adult male sockeye examined during tag application in the Seymour River, 1995. Values are not corrected for sex identification errors.

Date	Number examined	Net marks		Lamprey marks		Hook marks		*F. columnaris* [a]	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
19-Aug	0	-	-	-	-	-	-	-	-
20-Aug	17	2	11.8%	3	17.6%	0	0.0%	-	-
21-Aug	26	3	11.5%	2	7.7%	2	7.7%	-	-
22-Aug	21	1	4.8%	2	9.5%	0	0.0%	-	-
23-Aug	24	0	0.0%	1	4.2%	0	0.0%	-	-
24-Aug	23	1	4.3%	1	4.3%	0	0.0%	-	-
25-Aug	33	4	12.1%	3	9.1%	1	3.0%	-	-
26-Aug	52	1	1.9%	5	9.6%	0	0.0%	-	-
27-Aug	78	3	3.8%	4	5.1%	0	0.0%	-	-
28-Aug	57	3	5.3%	3	5.3%	0	0.0%	-	-
29-Aug	61	10	16.4%	0	0.0%	1	1.6%	-	-
30-Aug	49	2	4.1%	0	0.0%	0	0.0%	-	-
31-Aug	36	0	0.0%	0	0.0%	0	0.0%	-	-
1-Sep	20	0	0.0%	1	5.0%	1	5.0%	-	-
2-Sep	17	1	5.9%	3	17.6%	1	5.9%	-	-
3-Sep	14	0	0.0%	0	0.0%	0	0.0%	-	-
4-Sep	9	1	11.1%	2	22.2%	0	0.0%	-	-
5-Sep	8	1	12.5%	1	12.5%	0	0.0%	-	-
6-Sep	3	1	33.3%	0	0.0%	0	0.0%	-	-
7-Sep	0	-	-	-	-	-	-	-	-
8-Sep	2	0	0.0%	0	0.0%	0	0.0%	-	-
Total	550	34	6.2%	31	5.6%	6	1.1%	-	-

[a] Incidence was not recorded in 1995.

Appendix 4b. Incidence of net, lamprey and hook marks and of *Flexibacter columnaris* lesions among adult female sockeye examined during tag application in the Seymour River, 1995. Values are not corrected for sex identification errors.

Date	Number examined	Net marks		Lamprey marks		Hook marks		*F. columnaris* [a]	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
19-Aug	0	-	-	-	-	-	-	-	-
20-Aug	9	1	11.1%	1	11.1%	0	0.0%	-	-
21-Aug	19	2	10.5%	0	0.0%	1	5.3%	-	-
22-Aug	5	0	0.0%	0	0.0%	1	20.0%	-	-
23-Aug	9	1	11.1%	0	0.0%	0	0.0%	-	-
24-Aug	16	1	6.3%	0	0.0%	0	0.0%	-	-
25-Aug	28	1	3.6%	1	3.6%	0	0.0%	-	-
26-Aug	41	6	14.6%	0	0.0%	1	2.4%	-	-
27-Aug	59	4	6.8%	2	3.4%	0	0.0%	-	-
28-Aug	40	2	5.0%	1	2.5%	1	2.5%	-	-
29-Aug	40	7	17.5%	1	2.5%	0	0.0%	-	-
30-Aug	26	1	3.8%	0	0.0%	0	0.0%	-	-
31-Aug	28	4	14.3%	1	3.6%	0	0.0%	-	-
1-Sep	18	1	5.6%	0	0.0%	0	0.0%	-	-
2-Sep	12	2	16.7%	0	0.0%	0	0.0%	-	-
3-Sep	13	0	0.0%	1	7.7%	0	0.0%	-	-
4-Sep	13	2	15.4%	1	7.7%	0	0.0%	-	-
5-Sep	6	2	33.3%	0	0.0%	0	0.0%	-	-
6-Sep	5	0	0.0%	1	20.0%	0	0.0%	-	-
7-Sep	1	0	0.0%	0	0.0%	0	0.0%	-	-
8-Sep	1	1	100.0%	0	0.0%	0	0.0%	-	-
Total	389	38	9.8%	10	2.6%	4	1.0%	-	-

[a] Incidence was not recorded in 1995.

Appendix 4c. Incidence of net, lamprey and hook marks and of *Flexibacter columnaris* lesions among jack sockeye examined during tag application in the Seymour River, 1995. Values are not corrected for sex identification errors.

Date	Number examined	Net marks		Lamprey marks		Hook marks		*F. columnaris* [a]	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
19-Aug	0	-	-	-	-	-	-	-	-
20-Aug	0	-	-	-	-	-	-	-	-
21-Aug	0	-	-	-	-	-	-	-	-
22-Aug	0	-	-	-	-	-	-	-	-
23-Aug	0	-	-	-	-	-	-	-	-
24-Aug	0	-	-	-	-	-	-	-	-
25-Aug	0	-	-	-	-	-	-	-	-
26-Aug	0	-	-	-	-	-	-	-	-
27-Aug	0	-	-	-	-	-	-	-	-
28-Aug	0	-	-	-	-	-	-	-	-
29-Aug	0	-	-	-	-	-	-	-	-
30-Aug	0	-	-	-	-	-	-	-	-
31-Aug	1	0	0.0%	0	0.0%	0	0.0%	-	-
1-Sep	0	-	-	-	-	-	-	-	-
2-Sep	0	-	-	-	-	-	-	-	-
3-Sep	0	-	-	-	-	-	-	-	-
4-Sep	0	-	-	-	-	-	-	-	-
5-Sep	0	-	-	-	-	-	-	-	-
6-Sep	0	-	-	-	-	-	-	-	-
7-Sep	0	-	-	-	-	-	-	-	-
8-Sep	0	-	-	-	-	-	-	-	-
Total	1	0	0.0%	0	0.0%	0	0.0%	-	-

[a] Incidence was not recorded in 1995.

Appendix 5a. Daily sockeye salmon carcass recoveries, by recovery area, mark status and sex, in the Seymour River. 1995.

Date	Area	Number of surveys	Disk tag and/or secondary mark present			Unmarked			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
22-Aug	5	-	0	0	0	0	1	0	0	1	0
26-Aug	4	-	0	0	0	5	2	0	5	2	0
	5	-	1	0	0	2	0	0	3	0	0
27-Aug	4	-	0	0	0	4	0	0	4	0	0
	5	-	0	0	0	1	0	0	1	0	0
28-Aug	2	-	0	0	0	1	2	0	1	2	0
	4	-	0	0	0	1	1	0	1	1	0
	4a	-	0	0	0	1	2	0	1	2	0
	5	-	0	0	0	3	4	0	3	4	0
29-Aug	2	-	0	0	0	2	0	0	2	0	0
	4	-	1	0	0	13	3	0	14	3	0
	5	-	0	0	0	22	12	0	22	12	0
30-Aug	1	-	0	0	0	0	0	0	0	0	0
	2	-	0	0	0	7	2	0	7	2	0
	3	-	0	0	0	3	0	0	3	0	0
	4	-	0	0	0	7	6	0	7	6	0
31-Aug	5	-	0	0	0	23	13	0	23	13	0
	5a	-	0	0	0	9	1	0	9	1	0
	5b	-	0	0	0	5	0	0	5	0	0
1-Sep	2	-	0	0	0	4	2	0	4	2	0
	4	-	0	0	0	1	0	0	1	0	0
2-Sep	2	-	0	0	0	15	5	0	15	5	0
	4	-	1	0	0	38	14	0	39	14	0
	4a	-	0	0	0	64	11	0	64	11	0
	5	-	0 *	2	0	60	25	0	60	27	0
	5a	-	0	0	0	8	6	0	8	6	0
	5b	-	0	0	0	1	0	0	1	0	0
3-Sep	3	-	0	0	0	13	3	0	13	3	0
	4	-	3	2	0	136	61	0	139	63	0
	5	-	4	0	0	52	14	0	56	14	0
4-Sep	2	-	1	1	0	71	30	0	72	31	0
	4	-	0	0	0	9	11	0	9	11	0
	5	-	3	1	0	30	13	0	33	14	0
6-Sep	4	-	1	0	0	47	23	0	48	23	0
	5	-	1	0	0	46	19	0	47	19	0
	5a	-	2	0	0	13	15	0	15	15	0
	5b	-	0	0	0	3	1	0	3	1	0
7-Sep	1	-	2	0	0	4	3	0	6	3	0
	2	-	1	0	0	115	55	0	116	55	0
	3	-	1	0	0	3	2	0	4	2	0
	4	-	1	0	0	14	12	0	15	12	0
	5	-	0	0	0	46	8	0	46	8	0
8-Sep	4	-	17	8 *	0	476	388	0	493	396	0
	4a	-	4	2	0	245	159	0	249	161	0
	5	-	16	5	0	500	273	0	516	278	0

Continued

Appendix 5a. Daily sockeye salmon carcass recoveries, by recovery area, mark status and sex, in the Seymour River, 1995.

Date	Area	Number of surveys	Disk tag and/or secondary mark present			Unmarked			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Continued											
9-Sep	5a	-	1	0	0	44	39	0	45	39	0
	5b	-	0	0	0	6	0	0	6	0	0
10-Sep	1	-	0	1	0	11	18	0	11	19	0
	2	-	6	4	0	219	189	0	225	193	0
	3	-	0	0	0	19	22	0	19	22	0
	4	-	3	6	0	148	209	0	151	215	0
11-Sep	4	-	3	1	0	162	227	0	165	228	0
	4a	-	0	2	0	77	169	0	77	171	0
	5	-	7	7	0	240	282	0	247	289	0
12-Sep	1	-	0	0	0	16	18	0	16	18	0
	2	-	2	6	0	54	139	0	56	145	0
	3	-	1	0	0	16	12	0	17	12	0
	4	-	2	0	0	28	0	0	30	0	0
	5	-	0	0	0	11	0	0	11	0	0
	5a	-	1	0	0	22	26	0	23	26	0
	5b	-	0	0	0	3	1	0	3	1	0
13-Sep	4	-	5	5	0	91	213	0	96	218	0
	4a	-	0	0	0	35	63	0	35	63	0
	5	-	2	6	0	102	188	0	104	194	0
14-Sep	1	-	0	0	0	2	8	0	2	8	0
	2	-	0	0	0	18	49	0	18	49	0
	3	-	0	0	0	13	14	0	13	14	0
	5	-	0	2	0	4	31	0	4	33	0
	5a	-	0	0	0	21	29	0	21	29	0
	5b	-	0	0	0	2	7	0	2	7	0
15-Sep	4	-	0	0	0	72	122	0	72	122	0
	4a	-	1	0	0	17	27	0	18	27	0
	5	-	1	1	0	60	159	0	61	160	0
16-Sep	1	-	0	0	0	2	4	0	2	4	0
	2	-	1	1	0	14	52	0	15	53	0
	3	-	1	0	0	11	5	0	12	5	0
17-Sep	4	-	0	0	0	20	33	0	20	33	0
	4a	-	0	0	0	3	2	0	3	2	0
	5	-	0	0	0	31	44	0	31	44	0
	5a	-	0	0	0	1	9	0	1	9	0
	5b	-	0	0	0	0	0	0	0	0	0
18-Sep	1	-	0	0	0	0	1	0	0	1	0
	2	-	0	0	0	0	4	0	0	4	0
	3	-	0	0	0	0	0	0	0	0	0
	4	-	0	0	0	1	10	0	1	10	0
	5	-	0	0	0	2	5	0	2	5	0
	5a	-	0	0	0	0	3	0	0	3	0

Continued

Appendix 5a. Daily sockeye salmon carcass recoveries, by recovery area, mark status and sex, in the Seymour River. 1995.

Date	Area	Number of surveys	Disk tag and/or secondary mark present			Unmarked			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Continued											
Total	1	7	2	1	0	35	52	0	37	53	0
	2	12	11	12	0	520	529	0	531	541	0
	3	8	3	0	0	78	58	0	81	58	0
	4	19	37	22 [a]	0	1,273	1,335	0	1,310	1,357	0
	4a	7	5	4	0	442	433	0	447	437	0
	5	19	35 [a]	24	0	1,235	1,091	0	1,270	1,115	0
	5a	8	4	0	0	118	128	0	122	128	0
	5b	7	0	0	0	20	9	0	20	9	0
	Total	-	97 [a]	63 [a]	0	3,721	3,635	0	3,818	3,698	0

[a] Excludes one sockeye recovered less than five days after tagging.

Appendix 5b. Opportunistic recoveries of sockeye carcasses by beach seine net, by mark status and sex, in the Seymour River. 1995.

Date	Area	Number of surveys	Disk tag and/or secondary mark present			Unmarked			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
10-Sep	2	1	1	1	0	36	104	0	37	105	0
12-Sep	2	1	0	1	0	19	64	0	19	65	0
Total		2	1	2	0	55	168	0	56	170	0

Appendix 6. Daily sockeye salmon carcasses examined and disk tags recovered, by recovery area and sex, in the resurvey of the Seymour River, 1995.

Date	Area	Number of surveys	Disk tag present			Total examined			Disk tag incidence		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
3-Sep	4a	-	0	0	0	52	5	0	0.000	0.000	-
	5	-	0	0	0	83	31	0	0.000	0.000	-
9-Sep	4	-	1	0	0	440	234	0	0.002	0.000	-
	5	-	0	0	0	444	194	0	0.000	0.000	-
10-Sep	1	-	0	0	0	11	18	0	0.000	0.000	-
	2	-	0	0	0	37	44	0	0.000	0.000	-
11-Sep	3	-	0	0	0	13	2	0	0.000	0.000	-
	4a	-	0	0	0	182	190	0	0.000	0.000	-
12-Sep	1	-	0	0	0	7	8	0	0.000	0.000	-
	2	-	0	0	0	67	88	0	0.000	0.000	-
	5a	-	0	0	0	31	32	0	0.000	0.000	-
	5b	-	0	0	0	3	1	0	0.000	0.000	-
13-Sep	5	-	0	0	0	273	213	0	0.000	0.000	-
14-Sep	4	-	0	0	0	87	138	0	0.000	0.000	-
15-Sep	3	-	0	0	0	14	9	0	0.000	0.000	-
Total	1	2	0	0	0	18	26	0	0.000	0.000	-
	2	2	0	0	0	104	132	0	0.000	0.000	-
	3	2	0	0	0	27	11	0	0.000	0.000	-
	4	2	1	0	0	527	372	0	0.002	0.000	-
	4a	2	0	0	0	234	195	0	0.000	0.000	-
	5	3	0	0	0	800	438	0	0.000	0.000	-
	5a	1	0	0	0	31	32	0	0.000	0.000	-
	5b	1	0	0	0	3	1	0	0.000	0.000	-
Total	-	-	1	0	0	1,744	1,207	0	0.0006	0.000	-

Appendix 7. Fecundity sampling results and analytic details for sockeye salmon captured in the Seymour River, 1995.

Age	Standard length (cm)*	Skein weight (g)	Skein sub-sample		Estimated fecundity	Actual fecundity	Loose eggs	Adjusted fecundity
			Weight (g)	Egg count				
4_2	48.6	224.7	102.4	1,159	2,543		0	2,543
4_2	50.1	321.3	109.1	1,235	3,637		2	3,639
4_2	51.6	385.2	130.6	1,281	3,778		0	3,778
4_2	52.1	407.4	137.8	1,447	4,278		10	4,288
4_2	52.8	321.5	109.2	1,333	3,925		0	3,925
4_2	53.2	332.1	112.7	1,259	3,710		10	3,720
4_2	53.4	384.5	193.3	1,983	3,944	3,983	0	3,983
4_2	53.5	459.9	153.3	1,599	4,797		0	4,797
4_2	53.6	347.8	117.8	1,422	4,198		10	4,208
4_2	54.2	429.3	145.1	1,339	3,962		0	3,962
4_2	54.2	415.0	140.0	1,424	4,221		10	4,231
4_2	54.6	458.3	154.7	1,361	4,032		0	4,032
4_2	54.8	376.1	122.4	1,118	3,435		10	3,445
4_2	54.9	447.4	151.3	1,578	4,666		2	4,668
4_2	55.0	443.7	150.0	1,631	4,824		0	4,824
4_2	55.0	381.2	129.0	1,579	4,666		10	4,676
4_2	55.4	552.3	186.2	1,952	5,790		11	5,801
4_2	55.7	384.0	201.8	2,161	4,112	4,081	10	4,091
4_2	56.2	511.2	112.4	1,565	7,118		0	7,118
4_2	57.6	492.4	166.1	1,774	5,259		10	5,269
5_2	62.1	576.6	262.7	2,225	4,884	4,917	0	4,917
5_2	62.7	486.0	220.5	1,968	4,338	4,321	11	4,332
n/r	-	513.4	235.7	2,300	5,010	4,942	0	5,010
n/r	-	493.8	167.5	1,463	4,313		0	4,313
n/r	-	435.3	147.3	1,485	4,388		0	4,388
Means								
4_2 (n=20)	53.8	403.8	141.3	1,510	4,345	4,032		4,350
5_2 (n=2)	62.4	531.3	241.6	2,097	4,611	4,619		4,625

Appendix 8. Proportion at age and mean length (Standard and POH) at age, by location, sex and sample period,

Location	Sex	Sampling date	Age	Sample size	Percent	Standard length (cm)		POH length (cm)	
						Mean	Standard deviation	Mean	Standard deviation
Seymour River	Male	Total	4_2	163	92.6%	57.3	1.8	49.4	1.5
			5_2	13	7.4%	63.4	1.6	55.0	1.6
			Unaged	4	-	56.1	3.2	48.5	3.0
	Female	Total	4_2	163	91.1%	53.3	1.7	47.8	1.5
			5_2	16	8.9%	60.1	1.8	53.8	1.4
			Unaged	1	-	53.2	-	47.5	-